The Dock and Harbour Authority

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Editorial Comments

The Port of Houston.

The Port of Houston is a spectacular example of the growth of a modern port, for although it has been in existence only for some 35 years, it is claimed that, since 1948, it has ranked second among United States ports on a tonnage handling basis—a remarkable accomplishment which has contributed greatly to the industrial development of the Houston area.

As might be expected from its geographical situation, cotton and grain form the major export shipments from the Port. The latter, it is expected, will greatly increase in the immediate future by reason of a forthcoming international arrangement for the United States to supply grain to India, much of which will be shipped from the mid-West through the Port of Houston, the logical place for its export. Other major cargoes dealt with are chemicals and fertilisers, and oil and oil derivatives, from the Texas oilfields, while the chief imports are steel and steel products from Belgium, Sweden and elsewhere; besides general commodities, which are showing a steady increase in volume.

Situated some fifty miles from the deep waters of the Gulf of Mexico, access to the Port is by the Houston Ship Channel, which, for half a century, has undergone constant widening and deepening. Authorization has now been given by Congress for further improvement to a minimum depth of thirty-six feet throughout its entire course and turning basin, the latter being 1,100 feet in diameter. In view of the increasing draft of modern oil tankers, however, it is probable that the depth will eventually be increased to forty feet, as far inland as certain oil refineries, which lie some four miles seaward of the industrial port.

The article on a following page briefly deals with the Port of Houston, and more particularly with the construction of two new wharves, which have been recently completed, some interesting new methods being employed. The principal innovation of their design is the use of a series of interlocking cells constructed of steel sheet piling, to act as a cofferdam which, filled with compacted sand, serves as the base upon which to construct the wharf superstructure, a retaining wall and a surface concrete apron. This type of construction has become prominent in recent years both on the Continent of Europe and in America. The rolled steel sections, specially designed with strong interlocks to withstand tension of the order of 12,000 pounds per linear inch of interlock, are manufactured for the construction of cellular cofferdams of the type described. There are, however, in this country and elsewhere, several existing sections of steel piling, which, although not intended for such use, can nevertheless be so employed.

Our readers will remember that, in the June and July 1950 issues of this Journal, an article was published giving details of the design and construction of a cellular cofferdam at the Port of Curacao, to which reference can be made by those interested. In the case of the Port of Houston, the economic and engineering conditions of the site seem to have justified the method of construction, for the cost of both wharves resulted in a saving of about 30 per cent. on the estimated expenditure for wharves and quays of the conventional American type which usually comprise piles and concrete decking.

From this it seems that cellular substructures for wharves have possibilities in certain situations, which might well be further explored in this country.

Study Courses for Port Workers.

It is satisfactory to learn that good progress has been made with the formation of classes in the United Kingdom in connection with the Education Scheme for Port Workers, to which reference was made in our issue for March last. The response from many grades of port workers has been encouraging, and at a recent meeting of the "Central Body," appointed to represent educational interests, and both sides of the dock and harbour industry, the courses of study submitted by local technical and commercial colleges in connection with the scheme were agreed, and approval in principle was given to the syllabuses proposed for classes at Goole, Grimsby, Hull, Leith, Liverpool, Middlesbrough, Manchester, South Shields and West Hartlepool.

As stated in our March issue, the courses will comprise the study of three subjects : (a) Port Traffic, (b) Port Working, and (c) Port Organisation and Finance. This Journal has now agreed to collaborate in the scheme by publishing three articles dealing with each of the respective subjects, conveniently divided into sections, to provide the material on which the lectures should be based. The first article will be found on a following page, and subsequent articles will appear in the issues for September and October.

At this stage of the students' education, the presentation of the lectures must, of necessity, be elementary, and the lecturer will probably have to make some amendments to the matter set out for his information, so that it should be directly applicable to the particular port from which his class happens to be drawn. Nevertheless, the three articles will cover the essential features of the subject with which they deal, and will thus form a reliable basis from which to work.

Report of British Transport Commission.

The report of the British Transport Commission, which is reviewed on a later page, follows the pattern of previous years. As forecast, a deficit is again shown, although this is smaller than that of the previous year, chiefly due to increases in charges.

The Commission has taken the opportunity of expressing vigorously, objection to the difficulties under which it is forced to labour. It is, indeed, placed in an unenviable position, being

Editorial Comments—continued

expected on the one hand to show a profit from one year to another, whilst constantly subjected to criticism, in Parliament and outside, if it attempts to adjust its economy to meet changing conditions. The vigour with which this case is put is most welcome, although the suggestion that the Commission should enjoy much more freedom to increase railway rates, dock dues and canal tolls must be viewed with a trace of suspicion. The consumer has always enjoyed some protection, and there is every reason for this protection to continue now that the Commission has an effective monopoly over much of the country's transport.

We do, however, most heartily endorse the Commission's criticism of some of the opposition which arises whenever it attempts to achieve some economy in operation, whether by jettisoning superfluous and uneconomic services, or by introducing any innovation in operating methods. Where such opposing interests have no alternative to suggest, except that the particular uneconomic service should continue to be provided at the expense of the community, for the benefit of the few, they should be given slight consideration.

The Commission also makes an appeal for an acceleration of the procedure for an adjustment in its charges, where this is unavoidable. We likewise applaud this appeal, especially if we may expect a similar acceleration in the operations which precede a decision by the Commission on such major issues as the transfer of ports and an agreed policy concerning the future of the canals.

It is gratifying to read that the Commission does not necessarily assume that transfer of Ports to the Docks and Inland Waterways Executive will be the best means of ensuring re-organisation. Each case will be considered on its merits, which have been analyzed in reports now under consideration, and we hope, shortly to be published. The need for an early decision can hardly be overstressed, as we have frequently observed.

Canal operations again show a deficit on nett receipts, but we are pleased to observe that the problem of the expenditure upon little used canals, which should, in our view, often be preserved, but at the expense of other authorities, and not as a charge upon the Commission's activities, is apparently receiving serious attention.

International Congress of Refrigeration.

The fact that His Majesty the King has consented to become Patron of the Eighth International Congress of Refrigeration indicates the great progress made in this modern branch of engineering, and the forthcoming Congress which is to be held in London from August 29th to September 11th, under the Presidency of Viscount Bruce of Melbourne, will also reflect, both in the Papers read and the industrial plants visited, the innumerable services rendered by refrigeration to our present civilisation.

The rapidly increasing number of refrigeration engineers and technicians, many of whom will assemble at the forthcoming Congress, will have the opportunity of seeing the application of refrigeration to all manner of manufacturing plants, chemical and other processes, as well as to the storage and handling of perishable goods. The knowledge that Britain has so much to show the world in this direction is expected to draw a large number of visitors from overseas, both from the British Commonwealth and from most, if not all, of the fifty odd countries whose governments are members of the International Institute of Refrigeration. These visitors will be able to join in an extensive programme of industrial visits at which refrigerating installations will be exhibited to Congress members, and receptions accorded by sundry authorities and Corporations. The British Government will provide accommodation for the meetings at Church House, Westminster, and official receptions will be accorded to delegates in London and other parts of the country. The Institute of Refrigeration, which is the oldest national society of refrigeration in the world, and the British Refrigeration Association, will offer hospitality to Congress members.

The scope of the papers covers a wide range of subjects, and extends, on the one hand, into the highly scientific realm of low temperature and thermo dynamics. Those of a more practical nature deal with the designs of refrigerating machinery and the application of refrigeration to food storage and transport. On a subsequent page will be found details of the Congress, and the seven sections into which it is divided, together with some of the papers which may be of more particular interest to readers of this Journal.

Dock Labour at the Port of Antwerp.

The annual report recently issued by the Centrale des Employeurs du Port d'Anvers contains some interesting information concerning dock labour at the Port of Antwerp. The average handling capacity for all classes of traffic, except bulk oil, rose from 7.2 tons per worker per shift in 1948, to 7.7 tons in 1949, but dropped to 7.3 tons in 1950. Excluding bulk cargoes such as oil, coal, ore and grain, the quantities handled were 3.62, 4.25 and 4.15 tons respectively. The rise in the basic figure in 1949 was the result of employing improved handling methods and technical appliances, and the slight, but regrettable recession in 1950, was accounted for by strikes, which disrupted normal working conditions.

The report also analyses the standard of wages and its incidence on handling charges, and shows that the rate of pay at Antwerp (besides other Belgian ports) is much higher than at many other European countries, but the difference is largely off-set by a higher standard of efficiency, especially where general traffic is concerned. In this connection, it is interesting to note that the volume of general cargo handled, which decreased from 11.5 million tons in 1938 to 10.6 million tons in 1948, rose to over 11 million tons in 1949 and 12 million tons in 1950, so that pre-war totals have now been exceeded.

The Centrale des Employeurs du Port d'Anvers is the body acting as the liaison between Antwerp shipping interests and dock labour. It is a progressive organisation, supplemented by a number of sub-committees, including a joint committee of employers and labour, and a permanent bureau dealing with many matters appertaining to port working. It also attends to the payment of wages, including unemployment, pensions and insurance contributions, which involves the management of a complicated accountancy system and the responsibility for keeping separate accounts for each of the individual employers and men.

New Port of Nacala, Mozambique.

It will be remembered that a description of the Ports of Portuguese East Africa formed the leading article in the August 1950 issue of this Journal, and details were given of plans for a project to build a port at Nacala. We now learn that the first stage of construction, which included the building of a pier for lighters, has been completed, and it is expected that the Port will be open to navigation within the next few weeks.

The second stage of development will include a deepwater wharf 300 metres in length, with a depth of water alongside of 9 metres, and the provision of adequate cargo handling equipment.

As the railway from the Port already extends nearly 600 kilometres inland, and is now only 70 kilometres from the Nyasaland border, it is confidently expected that Nacala will eventually become a major Port serving Nyasaland, Northern Rhodesia and the Lower Congo, in addition to Portuguese East Africa.

Turn-round of Shipping in Australia.

During the last few months, reports have frequently appeared in the press concerning the long delays and slow turn-round of ships at Australian ports. It has now been announced that several shipping companies have adopted a new system of discharging cargo, in an endeavour to effect an improvement. Instead of discharging mixed cargo at a number of ports on the Australian coast, these companies are bringing ships with full mixed cargoes to one port and discharging the whole of it at that port.

An official of one of the shipping companies is reported as saying that each Australian port represented a hurdle to be overcome by shipowners, and by discharging at one port only, the number of hurdles was reduced. Having regard to the time taken in dealing with the usual customs formalities, the opening and closing of ships' holds, and the preparation of the ship for discharge, or for proceeding to sea, it is obvious that a considerable saving in time should be effected on each voyage. The new system was first tried last year, and since then has been continued, as it shows an encouraging improvement in the speed of unloading.

The Port of Houston, U.S.A.

A Modern and Progressive Port

(Specially Contributed)

SITUATED on the Houston Ship Channel in South Eastern Texas 50 miles from the Gulf of Mexico, and surrounded by numerous oil fields, the Port of Houston serves a wide industrial hinterland. The original settlement which was named after General Sam Houston, was founded soon after the battle of San Jacinto, in 1836, and since that date, in little more than 100 years, the village has grown into an important city with a population of over 596,000 (1950). It is also the second port of the United States of America, in terms of the volume of shipping and the total tonnage of goods handled over the wharves. Since the First World War, the city has made rapid commercial and industrial development, and to-day it has five commercial air ports, and is served by numerous railways and by 95 steamship lines operating to the principal ports of the world. In 1950 more than 3,200 ships moved in and out of the port, and the tonnage of goods handled amounted to 41,995,143 short tons.

The port, some four miles east of the city, is favourably situated to serve a wide area, as it is a terminal of the Intracoastal Canal which gives it direct access to about 7,000 miles of inland waterways. It is administered by the Harris County Navigation and Canal Commission, and all the public facilities and Port Terminal Railroad are owned by the Navigation District. There are four privately owned terminals for hire on the Houston Ship Channel, Long Reach Terminal, Manchester Terminal, Sprunt Docks and Adams Terminal. These, together with numerous private industrial docks, provide berths for 79 deep sea vessels.

Houston's economic progress has been bound up with the navigable waterway to the Gulf of Mexico ever since "sailing boats and flat-bottomed barges made their way up and down the shallow and meandering tide-water stream in the early days of the village." Large sums of money have been spent on improving the channel and providing harbour facilities, and by 1940 the total expended on these projects by the Federal Government and the citizens of the Harris County Navigation District amounted to some $45,000,000.

It was only 35 years ago that the first ocean-going vessel steamed out of the port, when in 1915, a channel with a depth of 25-ft. was completed from the Turning Basin to Galveston Bay. A few years later the channel was widened and deepened successively to 30-ft., 32-ft. and 34-ft. It is now being deepened to 36-ft.

An article in the March, 1951, issue of "World Ports," the official organ of the American Association of Port Authorities, ascribes the growth of the port in the past ten years to an energetic campaign of port promotion carried out by the Houston Port and Traffic Bureau throughout the world, and to the constant improvement of terminal facilities to maintain an economical and efficient service. The Bureau is the sales and advertising organization for the port which is incorporated on similar lines to the average Chamber of Commerce. It is financed by a number of interests including terminal operators, forwarding agents, shipping, banking and other business organizations. It operates as a separate entity, but is governed by a Board of Directors who work in close association with the Harris County Houston Ship Channel Navigation District.

Since 1945, nearly 23 million dollars has been spent on port improvements including construction of buildings and the purchase of new equipment and modern handling facilities. A new $4,000,000 terminal (Adams Terminal), has been added to the

Port of Houston. Aerial view of the Turning Basin and Houston Ship Channel.

The Port of Houston, U.S.A.—continued

three private and one public, terminals for hire, and two modern wharves, described in detail below, have been built. In addition nine others have been remodelled at a cost of a further 4 million dollars.

Another improvement which has been effected is to the railway system, in which the major railway companies co-operate with the waterway to speed traffic between the dockside and the railroad. One of the two large underwater tunnels has been completed at a cost of $8,000,000 and plans to still further improve the ship channel by widening and deepening to 40-ft. have received consideration. Two recent projects to make the waterway navigable to the largest ocean-going vessels are making good progress.

The port expansion works have brought ships and cargo into Houston in increasing numbers and the port facilities have provided a great impetus to private trade and industrial concerns. For example, for the repair of ships using the port, there are a number of ship repair yards with dry docks, and it was in these yards that a number of Liberty ships were built during the war.

Again, access to the sea and sea transport has assisted numerous oil refineries to exploit the oil resources in the neighbourhood, and chemical and allied plants and other industrial development has shown steady expansion during recent years.

Further, due to its geographical position and the facilities offered, the export of cotton forms an important item of the port's trade, while large quantities of grain are shipped overseas. As much as 60 million bushels of grain have been handled in a year, at the port's public grain elevator, which has a capacity of 3,500,000 bushels.

New Wharves of Cellular Bulkhead Design

By FRANK H. NEWNAM, Jr.
Partner, Lockwood and Andrews, Consulting Engineers, Houston, Texas.

ORIGIN OF DESIGN

In 1948 the Board of Commissioners of the Port of Houston decided to find a way to construct more economical wharves, without resorting to temporary or so-called semi-permanent types of construction.

The first project to be considered was Wharf No. 9, which was intended to replace two adjacent old timber wharves that eventually failed when an underlying stratum of fine sand, 30-ft. below the water, washed out into the harbour. The engineering staff of the port prepared plans for the proposed new wharf, employing the open-type sub-structure that had previously been used successfully in the area, with the mudline cut back underneath the wharf at a 1-in-3 slope. The apron and transit shed were to be supported on a structural concrete deck founded on concrete piling.

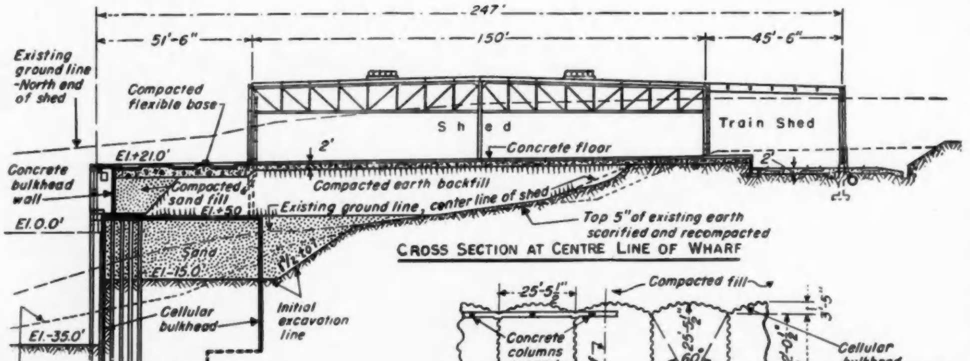

Fig. 1. Cross-section of new Wharf and Transit Shed.

The transit shed plans called for a riveted steel frame and concrete roof.

Preliminary estimates for the project indicated excessive costs under the prevailing price conditions. The Port Commission then engaged Messrs. Lockwood & Andrews, Consulting Engineers, to develop, if possible, an equally satisfactory but more economical design.

This firm, with the assistance of Mr. S. J. Buchanan, its consultant on soil mechanics and foundation engineering, and former head of soil mechanics research for the Corps of Engineers, obtained tests on undisturbed samples taken from extensive soil borings at the site. Utilizing these data, the consultants made engineering studies on four new types of design, as well as on the conventional concrete-piling type. The final recommendation was that the cellular steel bulkhead type of substructure with a front concrete wall appeared to be the most economical type for the site conditions, consistent with modern design, high stability and permanence. Redesign of the transit shed was also recommended. Both these recommendations were approved and the Consulting Engineers thereupon completed the designs, obtained tenders for the work, and subsequently supervised construction.

Eventually, owing to the phenomenal traffic increase on the Houston Ship Channel since the war, it was found necessary to provide a further wharf in addition to Wharf No. 9, which was completed in March, 1950, and a second wharf, known as Wharf No. 16, was therefore put in hand, and was completed early this year.

DETAILS OF WHARF NO. 9

Wharf No. 9 is situated at the head of the ship channel, which has a turning basin 1,100-ft. wide. The structure has the following principal features: length, 500-ft.; dock height at harbourline, 21-ft.; minimum depth of water, 36-ft.; design depth, 40-ft.; design loading, 500 pounds per square foot; front apron, 50-ft. x 500-ft.; with three railway tracks, enclosed transit shed, 150-ft. x 500-ft.; and a covered train bay, 45-ft. x 500-ft., containing loading platform and two railway tracks at the rear of the warehouse and a third track in the open. The project contained considerable appurtenances which added to the cost. These included connecting paved road and railway trackage, parking area, extension of the front apron, and a steel piling bulkhead at right angles to the wharf.

The marginal tracks are used principally for bulk cargo, such as billets and scrap iron; and the transit shed is used for general cargo of all kinds, such as coffee, rubber, cotton, etc. The cargo is palletized and handled by fork lift-trucks.

CELLULAR-BULKHEAD DESIGN

The pertinent features of this design are shown in the cross-section (Fig. 1). The principal innovation is a series of interlocked steel sheetpile cells, similar to those used in conventional cofferdam construction. These cells serve as a bulkhead behind the fender system and under the entire apron. The upper part of the cells is filled with compacted sand to provide rigidity.

A concrete wall supported on steel bearing piles extends from the top of the cells at the water line up to the apron, providing the harbour face of the wharf. Compacted earthfill, above the top of the cells and behind them, forms the foundation for the apron, shed floor and superstructure. This affords virtually unlimited allowable concentrated loading on these paved areas, although the structure is designed for a uniform apron and floor loading of 500 pounds per square foot, plus railway loads on the tracks.

The front of the cells extends well below the mudline of the

The Port of Houston, U.S.A.—continued

harbour and thus serves as an effective cut-off against the subsoil seepage, or wash, that proved detrimental to the two old adjacent wharfs already referred to.

The Port Commission authorized the preparation of contract plans and specifications and the taking of alternate bids, with the redesigned shed and all appurtenances in both alternates, but with two alternate types of substructure: (1) the concrete piling type, for which plans had already been prepared; and (2) the cellular bulkhead type as described above. The quotation of Farnsworth & Chambers Co. Inc., of Houston, at $1,734,693 was the lowest of three bids based on the cellular cofferdam type. This price was $404,476 less than the lowest of four bids on the concrete pile and structural deck design. It was estimated that a $65,000 saving was effected by the redesign of the transit shed; therefore the total saving directly attributable to the new design for Wharf No. 9 is approximately $470,000.

DETAILS OF CONSTRUCTION

Initial work on the construction of Wharf No. 9 consisted of removing existing soil at the north end of the site to an elevation of – 15-ft. This was done to facilitate driving the sheet piling in this most stable section of the site and to minimise the risk of driving the piles out of the interlocks. (The piles penetrated tough clay and had to be jetted as deep as to within 5-ft. of grade.) The

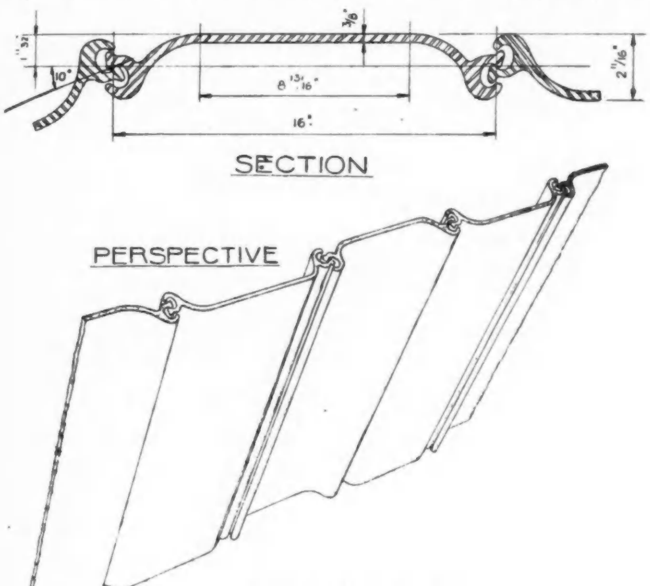

Fig. 2. Typical M 112 Sheet Pile.

pre-excavation also permitted filling inside and behind the cells with compacted selected clean sand vibrated into place to produce stability higher than that of the undisturbed soil. At the south end of the site the mudline was below the elevation of – 15-ft., and there it was necessary to remove only the original soil prior to driving the cells. These cells, which drove easily, were constructed of type M 112 sheetpiling formed around templates and driven by conventional methods used for cofferdams of the type (Fig. 2).

After enough cells had been driven, the steel bearing piles were driven in the front portion to support the front concrete wall. The cells were then filled with sand, as was the area behind the cells up to an elevation of 4-ft. The sand fill was placed in 5-ft. layers, special care being taken to ensure that the differential between the top of the sand in adjacent cells was not more than 5-ft. at any time. Each layer was vibrated with concrete spud-vibrators to ensure a pre-determined minimum density, which afterwards was verified by tests. After the sand fill had been completed, the front concrete wall, with buttresses on the harbour side, was formed and poured so as to rest on the bearing piles. The wall was also interconnected to the front row of the sheetpiling in the cells.

Following wall completion, the remaining fill, from elevation 4-ft. up to the apron and warehouse floor slab elevation, was

Fig. 3. Sheetpile cells driven around floating timber templets establish basic strength of new wharf.

placed with the aid of sheepsfoot rolling and optimum-moisture control. Concrete slabs were placed by normal paving methods, directly upon the compacted fill and a sand-shell sub-base. The 500-ft. x 150-ft. transit shed is of steel frame and truss construction.

Fig. 5 shows the earth fill being placed and compacted behind the front concrete wall, and Fig. 6 is a view along the harbour face of the completed wharf.

CHANGE IN DESIGN FOR WHARF 16

The second unit (Wharf No. 16) is located at the downstream entrance of the Turning Basin and the pertinent features are: 600-ft. of frontage; an apron 18-ft. above mean low tide; 36 feet of water, depth 40-ft. design depth; and two marginal railway tracks on the apron. This wharf contains 123,070 sq. ft. of paved area for open storage, designed for 500 lbs. per square ft. uniform loading, and extending back more than 200-ft. from the fender line. None of the area will be under cover, so that no shed structure is contemplated. It will be necessary, however, to construct a trestle connecting to land on the high bank immediately south of the wharf so as to permit proper switching of cars for loading and unloading.

This substructure likewise consists of a cellular sheetpile bulkhead behind the fender system; it differs from Wharf 9, however, in that deeper cells of heavier-section piles are required because the cells extend up almost to the apron floor. There is no concrete wall at the front and hence no bearing piles are needed. Compacted sand is used for the interior fill in order to impart required stability to the bulkhead. In the area behind the cells, vibrated sand is used below the waterline, and earthfill compacted with sheepfoot rollers is used above the waterline. The concrete paving is placed directly on the compacted fill, permitting the almost unlimited concentrated loading mentioned for Wharf No. 9.

Facilities are provided for transfer between ship, railway and motor truck. The project also required several appurtenant items of construction, including: connecting paved roads, railway trestle

Fig. 4. H-piles within cells at waterside support concrete wall that retains wharf's compacted fill. Timber templets positioned these piles too.

The Port of Houston, U.S.A.—*continued*

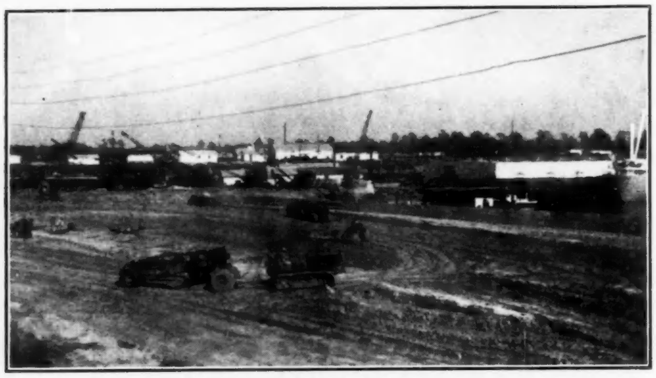

Fig. 5. Rolled fill is placed behind finished concrete wall. Cellular bulkhead lies below outer portion of fill.

and switching spur at one end, and a railway siding at the rear of the paved area. This wharf will be used for the handling of items that can be stored in the open, which at this port include such cargo as scrap iron, rail, pipe lumber and 50-gallon drums of various commodities. The marginal tracks will be used principally for unloading incoming cargoes such as ballast, scrap and billets. Magnetic lines will be placed along this wharf to facilitate these operations.

Here again, when preparing the designs the procedure was, first to make a series of borings at the site, test the undisturbed samples obtained, and thoroughly analyze the strengths at the various locations in comparison with the stresses imparted by various types of wharf design.

The soil conditions at Wharf No. 16 were found to be somewhat better than at the site of Wharf No. 9, so that a more economical modification of the cellular bulkhead substructure was recommended. The cells extend up to the apron floor, thus eliminating the need for the front concrete wall. Larger and deeper cells were required, however, as well as a heavier section type of sheet piling—all based on the calculated stresses.

The Port Commission authorized the Consulting Engineers, in co-operation with the Port Engineer, to prepare plans and specifications based on this design, and alternate plans based on another type considered in the report, namely, a straight bulkhead with two levels of tie rods. Farnsworth & Chambers Co., Inc., was again the lowest bidder and was awarded a contract for the construction of the cellular bulkhead type at a cost of $811,805. This price was estimated to be some $540,000 less than for the formerly conventional concrete pile and structural deck type of substructure.

The Consulting Engineers say in their report to the Port Development and Construction Committee of the American Association of Port Authorities, that "It can be seen that a saving of more than $1,000,000 has been made on the two new wharves, whose total cost will be approximately $2,500,000. This should not lead to the conclusion that the key to economy is to use cellular bulkhead designs for all wharves, because for many other sites and uses they would not be the most suitable or economical. Furthermore, constantly changing relationship between the availability and price of materials and labour affects the relative economy of different designs, and should be studied for each new project. The lesson to be learned from the foregoing account of this latest innovation at Houston is that thorough preliminary investigations, tests and engineering studies which utilize this information, are essential for the economical design of modern waterfront structures. More than in almost any other field of construction, the foundation conditions govern the choice, and the mere examination of borings is not sufficient. Tests on undisturbed samples must be carefully chosen, and full use made of the modern tool of soil science to arrive at strengths of various soils and the stresses imparted to them by various types of structures. These investigations cost money, but they almost invariably reap large dividends."

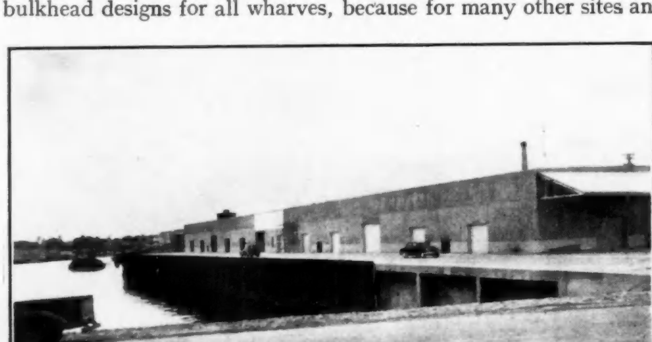

Fig. 6. View of completed Wharf No. 9.

British Transport Commission

Review of Third Annual Report

The 450 pages of the British Transport Commission's Report for 1950 deserves serious study from those interested in the economics of transport and the operation of a nationalized industry, in which efforts are being made to use the resources in the best possible manner. Of the Commission's gross receipts, about three-quarters represent those from the activities of the railways, and it is naturally to this field that most attention is directed. The total net revenue rose from £31.3 million to £40 million, as compared with 1949, but after providing for interest and other charges, the deficit for the year amounts to £14.1 million, which is a distinct improvement upon the £20.8 million in 1949. As a result of the continuing losses, it is probable that the Commission will be showing an accumulated deficit of about £50 million by the end of this year, and the Report shows that the Commission is seriously studying means to deal with this unhappy situation. Critics of the Commission have constantly observed that it must take steps to achieve economies by eliminating uneconomic services, if this situation is not to continue.

It is, however, clear that the Commission realises some of the other reasons which prevent it from achieving a balance between ever-rising costs and its inflexible charges, and especially the various restrictions which are imposed upon its activities. The Report stresses that the Commission is alone amongst the industrial and commercial organisations in Great Britain, in that it has little latitude for adjusting its charges in times of rising prices or falling traffic. For example, application for an increase in railway freight charges and dock and canal dues was only finally granted in May of the year under review, although the application was made in the previous November. Considerable sympathy can thus be felt for the Commission, and it is not surprising to observe that it is pressing vigorously for some relaxation in the complicated procedure which at present precedes any alteration in its charges. It would not, however, be in the public interest to condone a series of increases unless it was clearly evident that every possible economy had been affected. It is in this respect that the Report makes interesting reading, since statistics are given which show the relative cost of little used services as compared with main-line routes. For example, the cost per passenger mile on the branch line railway services of this country are no less than 50 times those of main-line services.

The Commission's admirable courage in giving publicity to these facts is applauded, and similar relative costs for dock and canal operation would be welcome, although these are, of course, fairly well known to those connected with these industries.

Having established that one way to more economical operation is to eliminate certain services, the Commission finds itself faced with enormous difficulties in putting these economies into effect. It is observed that the Commission has been faced with appeals to Consultative Committees and a constant stream of propaganda through various organisations when even any small changes are proposed. If the Report served no other useful function, it will

British Transport Commission—continued

at least have achieved some good by drawing attention to this dilemma.

If a case is made for the abandonment by the Railway Executive of uneconomic branch lines and the substitution of some other means of transport, a similar conclusion can be drawn in connection with those canals which carry little commercial traffic. The cost of these add to the burden of the canal carrying organisations, both nationalised and independent, operating on other routes in an efficient manner.

Apart from stressing the necessity for a scheme of public control over the general level of charges, which is both speedy and flexible in operation, the Commission still bases its hopes upon better integration between the various services. This, of course, relates to the proposed new charges scheme, which is due for submission to the Transport Tribunal by August 6th, and is expected to involve radical changes in the basis of charging by all services. There is a grave risk that the Commission may attempt to recover its losses by a substantial increase in charges on such traffic as minerals, upon which it has a virtual monopoly. This would be contrary to the principle which has been in force for many years, and such a change must not be too readily accepted, since it might succeed in allowing inefficient practices to continue. The Commission, however, does show every sign of being convinced of its case, and of the rightness of its cause, and such an approach at least indicates an enthusiasm which might very well be lacking, although an impression that defects of organisation and policy are being veiled somehow remains.

DOCKS AND HARBOURS

Readers of this Journal will naturally be especially interested in the Section of the Report which deals with port operation. The following extracts will tell of the activities of the Docks and Inland Waterways Executive during 1950 and give some indication of its policy for the future:—

REVIEW OF TRADE HARBOURS.

" The Docks and Inland Waterways Executive, to whom the duty was delegated by the Commission, have been keeping the trade harbours of the country under review in accordance with the provisions of Section 66 (2) of the Transport Act. They have paid visits to Aberdeen, Dundee, and the Ports of the River and Firth of Forth, to the Ports of the North East Coast, to the Cumberland Ports, to the Port of London, to Merseyside, Manchester and Preston, and to Bristol, and have presented to the Commission a series of reports upon their review. These reports contain much valuable and detailed information as to the constitution of the Authorities at present controlling these Ports, as to the facilities available, and as to the level of imports and exports passing through them, and the current problems with which they are faced. The Executive have also made recommendations for promoting efficiency and economy in the administration and development of a number of the ports reviewed, and the formulation of schemes under Part IV of the Transport Act with those objects in view. The Commission have authorized the Executive to proceed with consultations in regard to such schemes for the trade harbours of the River and Firth of Clyde, of the River Tees and the Hartlepools, and of Aberdeen. They are giving earnest consideration to the recommendations of the Executive in other cases, recognizing that they have a responsibility in relation to the future development of trade harbours in this country, in view particularly of the duty imposed by Section 3 of the Transport Act that the Commission should so exercise their powers as to provide, or secure or promote the provision of, an efficient, adequate, economical and properly integrated system of public inland transport and port facilities within Great Britain."

" It is not regarded as an essential or normal preliminary to reorganization that the ownership of these ports should pass into the Commission's hands, although in particular cases this solution may be found to be the best. Each case will be treated on its merits.

PROPOSED SCHEME FOR THE RIVER TEES AND THE HARTLEPOOLS.

" As recorded in the Second Annual Report, consultations with the bodies concerned took place in the autumn of 1949 on the proposal to prepare a Scheme under Section 66 of the Act.

" Following these consultations, a provisional Draft was prepared of a Tees and Hartlepools Trade Harbours Scheme and this was circulated in October to the bodies entitled to be consulted.

" This draft Scheme covered the trade harbours formerly owned by the L.N.E.R. at Middlesbrough, Hartlepool and West Hartlepool, and all other trade harbours within or adjoining the port of Hartlepool or the area within the jurisdiction of the Tees Conservancy Commissioners. By it the Commission would be specified as the body to provide port facilities under the Scheme, and to administer the Scheme by themselves or through their agents, but their functions under the Scheme would be performed by a Harbour Board, the Commission reserving to themselves powers to promote and oppose Bills in Parliament, to create or issue stock or borrow money on other than a temporary basis, to agree the compensation for the transfer of undertakings, and to dispose of any part of the undertaking, and also the necessary functions in relation to Charges Schemes.

" The Harbour Board would consist of a Chairman and eight other Members all appointed by the Commission. Six of the Members would be appointed from persons nominated by bodies representing shipping and traders using and workers employed in the harbours covered by the Scheme, two Members from each of the three interests mentioned. The remaining two Members would be persons of experience in public affairs or local government in the area.

" The Harbour Board would be required to obtain the prior approval of the Commission to schemes of development or improvement costing more than £25,000, the annual budget of receipts and expenses, the form and nature of accounts and the appointment of chief officers.

" The Scheme provided for the transfer to the Commission of a number of harbour undertakings and for the payment of compensation in respect of the transfer. The licensing provisions of Section 67 of the Transport Act would apply from a day to be appointed by the Commission.

" The Scheme also contains provision for payment of compensation to officers and servants of a transferor who suffer loss of employment or loss or diminution of emoluments or pension rights or whose position is worsened in consequence of the transfer of a harbour undertaking under the Scheme.

" Late in December the Executive reported to the Commission the observations and objections which they had received as a result of their consultations on this draft Scheme with the bodies concerned, and the Scheme was submitted to the Minister early in 1951.

PROPOSED SCHEME FOR THE CLYDE AREA.

" As recorded in the Second Annual Report, the Commission requested the Docks and Inland Waterways Executive to proceed with the necessary arrangements for the statutory consultations preliminary to the presentation of a Scheme for the River and Firth of Clyde and the Ayrshire coast.

" The Executive wrote to the bodies concerned in December, 1949, setting out alternative methods which might be adopted to produce the desired unification, and the consultations in the area took place early in 1950.

" The consultations revealed considerable differences of view as to the desirability and scope of unification and as to the methods by which it should be secured. Nevertheless, there was support for the view that the administration of the trade harbours and of conservancy matters in the Clyde area and the planning of future developments, which would inevitably prove expensive, should be in the hands of a single body responsible for the River and Upper Firth, who would be able to view its needs and potentialities and those of the shipping and trade of the area as a whole. It was, however, generally agreed that the ports of the Ayrshire Coast should not be embraced in the Scheme.

" After considering with the Executive all the views expressed by the persons and bodies consulted, the Commission decided that a Scheme should be prepared covering the trade harbours of the Clyde, and a provisional draft of the Scheme was circulated early in 1951 to the bodies and persons entitled to be consulted under the provisions of Part IV of the Act.

British Transport Commission—continued

PORT OF ABERDEEN.

" In their report on the Port of Aberdeen, the Docks and Inland Waterways Executive drew attention to the fact that the authority of the Harbour Commissioners, who at present administer the Port under the Aberdeen Harbour Acts 1895 to 1950 is due to expire in 1956, and that it is, therefore, desirable that an early decision should be taken in regard to the future administration of the Harbour. The Harbour Commissioners consist of 31 Members, of whom 19 are appointed by the Aberdeen Corporation, and the remaining 12 are elected by the payers of dues, and it was considered that the body is too large and is not sufficiently representative of the trading interests using the port and the workers employed in it.

" In their recommendations to the Commission, the Executive expressed the view that on account of the comparatively isolated geographical situation of the Port of Aberdeen there would be no advantage in grouping it with other Ports on the East Coast of Scotland, such as Dundee or the Ports of the Firth of Forth. They considered that many of the points raised in the course of their review could appropriately be dealt with in a scheme under Section 66 of the Transport Act, and that such action would commend itself to important sections of local opinion. They therefore suggested that they should be authorized to consult with the appropriate bodies with a view to the formulation of a scheme which should provide for the future administration of the Port, for reduction in size and reconstitution of the managing body, and for a measure of control over projected capital expenditure at the Port.

" On consideration of this report, the Commission have agreed that the Port of Aberdeen should be dealt with in isolation and have requested the Executive to proceed with the necessary consultations in relation to the formulation of a scheme under Section 66 of the Act. The Executive accordingly proceeded with the necessary consultations in accordance with the provisions of Section 66 of the Act, and their report on these consultations was awaited by the Commission at the end of the year."

VISITS TO OTHER PORTS.

With regard to the visits to the port areas of London, Bristol, Cumberland and Dundee, the Report says :—

" In the course of the visits all aspects of the administration and operation of the ports were discussed with the port authorities and with the representatives of shipowners and traders using the ports, of workers employed and of employers engaged therein, and of the National Dock Labour Board.

" The visit to Dundee was the sequel to that paid during 1949, at which time the Executive were not able to complete their enquiries, partly as a result of the uncertainty then surrounding the jute industry on which the port has so largely depended in the past.

" The Executive again desire to acknowledge their indebtedness to the harbour authorities and other bodies for the assistance given and the courtesy extended to them on the occasions of their visits."

DEVELOPMENT.

" The continuing difficulties of the post-war period, including rising costs in the building and engineering industries and Government limitations upon capital investment have all contributed to a slowing down in the pace of development.

" The Commission have agreed in principle that steps should be taken to restore and improve war-damaged accommodation at the Riverside Quay and South Side, Albert Dock, Hull; the detailed scheme is now under examination by a firm of consulting engineers.

STATISTICS.

" The traffics dealt with in the Commission's docks showed a considerable improvement over those of 1949 in the early months of the year 1950, but in the latter part of the year there was a marked decline in trade, particularly in coal exports. As a result, the total cargoes inwards rose by 919,000 tons compared with 1949, while cargoes outward increased by only 44,000 tons. These increases, however, are more than accounted for by oil movements into and from South Wales, which increased by 1,494,000 tons and 1,400,000 tons respectively. The trade variations at the groups of docks have been as follows :—

	Inwards		*Outwards*	
	Increase tons	*Decrease tons*	*Increase tons*	*Decrease tons*
	000's	000's	000's	000's
Scottish	—	266	—	567
North Western	—	54	74	—
North Eastern	—	22	—	63
Humber	22	—	—	779
South Wales	1,273	—	1,340	—
Southern and South Western	58	—	113	—
Others	—	92	—	74
Net Increase ...	919		44	

" Coal traffics have been disappointing, outward shipments having fallen by 646,000 tons in the Scottish Ports, 203,000 tons in the North Eastern, 915,000 tons in the Humber and 142,000 tons in South Wales. The North Western Group of Ports, however, showed a small increase in coal shipments of 87,000 tons."

" The total working expenses show an increase of £11,000 as compared with 1949, but operating expenditure was reduced by £60,000, part of this decrease being due to the decline in tonnages shipped other than oil, and part to operating economies which were effected during the course of the year. Actual maintenance expenditure was little different in total, but the standard charge increased by £52,000 owing to increases in price levels. Steps are being taken to adjust the apparatus and equipment of the docks to known present and estimated future requirements and the accounts for the year reflect certain of the economies that have already been effected under this head."

TRAFFIC.

During 1950 the tonnages of imports and exports, including traffic carried coastwise, handled through the Commission's Docks, with corresponding figures for 1949, were as follows :—

Imports		*Exports*	
1949 Tons	1950 Tons	1949 Tons	1950 Tons
22,372,000	23,291,000	36,947,000	36,991,000

Of the exports in 1950, 28,996,000 tons consisted of coal and coke shipped foreign and coastwise, representing a reduction compared with the previous year of nearly 2,000,000 tons. There was again a striking improvement in the financial results, as the following figures show :—

All Commission-Owned Docks, Harbours and Wharves

	1948 £	1949 £	1950 £
Gross receipts ...	10,799,704	11,717,946	12,497,706
Working expenses	12,129,188	12,541,999	12,552,553
Deficit	1,329,484	824,053	54,847

The improvement in 1950 was due in large measure to the increased charges which came into force in May, but economies in expenditure and increased traffic played their part.

CHARGES.

Following the Commission's application to the Minister for an increase in dock charges to meet the unsatisfactory financial position due to rising costs, and the subsequent hearing by the Transport Tribunal acting as a Consultative Committee, the Minister by regulation dated 1st May 1950, authorized from 15th May an increase in dock dues and charges, other than labourage charges, to the extent of 50 per cent. in the case of coastwise traffic and 100 per cent. in the case of other traffic, over the charges in operation on 31st August, 1939.

Various non-statutory charges which were on an uneconomic basis have also been increased.

RAILWAY DOCKS.

The new ocean terminal at Southampton was opened for traffic on 31st July. A new motor-car examination hall at Dover for the clearance for accompanied motor-cars was brought into use in June, and greatly facilitated the handling of the heavy traffic. A major scheme was approved for the renewal of the jetty and other works of the eastern section of Parkeston Quay.

The control of a number of the smaller docks was transferred

British Transport Commission—continued

from the Railway Executive to the Docks and Inland Waterways Executive on 1st January and the railway dock at Goole on 15th July. The docks at Southampton were transferred on 1st September and arrangements were made for the co-ordination of the work of the two Executives at the port.

When the previous year's Report appeared, this Journal commented, in the October 1950 issue, that the uncertainty about the future of major ports, and the atmosphere of suspense, were not conducive to efficient operation and administration. It will be observed that during 1950 the Executive has been occupied in keeping under review the trade harbours of the country, and a series of Reports have been presented to the Commission which are both comprehensive and illuminating. It is to be hoped that these documents will shortly be released, since they must contain much of value and interest, and it is also to be hoped that decisions will not be long delayed on these important issues.

CANALS AND INLAND WATERWAYS

The Report shows that both Canal Carrying Operations and Canal Operations, other than carrying, were in deficit on nett revenue account for the year. This means that receipts were less than expenses before any contribution was made to general overheads and interest upon capital, and, of course, no such contribution was made from these activities. However, it would be unfair to allow these figures to speak for themselves, without further comment, as this would do less than justice to the staff of the various Divisions, who must generally have attacked their tasks with admirable vigour. Nor should this opportunity be missed to comment favourably upon the efforts of the boat crews, including those working for the independent carriers, who still handle the bulk of the traffic. The standard of hard work, often under adverse conditions, of captains and crews should serve as an example to the country generally, and is certainly appreciated by Divisional Officers and the management of independent carrying firms. Again, these waterway carrying companies have contributed much to the comparatively gratifying results.

Extracts from the Report, printed below, give details of the increase in traffic, and of some success in overtaking arrears of maintenance, resulting in greater efficiency and increased carrying capacity. They also show that the Executive is concentrating its endeavours upon waterways capable of passing estuarial craft of economic size, and also upon those narrow canals, which carry substantial traffic or are essential as alternative routes. There are one or two cases known where expenditure on canals of apparently little commercial utility has continued, but perhaps these have been earmarked for future development. If this proves not to be the case, when the Executive's plans for a co-ordinated waterways system are eventually released, such expenditure would have been most deplorable.

The case has been repeatedly made in this Journal that a decision upon future canal policy must be treated as a matter of urgency. Sir H. Osborne Mance said, in 1949, "What I wish to emphasise is the urgency of these investigations, and of a decision *now* on future canal policy. I cannot conceive the existing narrow canal system being maintained, except at a cost to the State out of proportion to its utility to the nation." The investigations were those which must precede a decision upon which canal routes would eventually be enlarged to accommodate estuarial craft, and those which would be abandoned or transferred to bodies better fitted to maintain them on account of their scenic or historic value, or for pleasure purposes. No direct reference is made to this necessary process of categorisation, and it must be admitted that the Executive may have been forced to be uninformative, in order to avoid premature opposition, and in fear of prejudicing negotiations in progress. It is not inappropriate to quote from the Report, where this refers to the closing of railway lines :—"the development of an integrated transport system obviously requires that services which no longer effectively answer a public need shall be withdrawn and replaced by other and more suitable facilities. . . . In this matter there is no clear-cut line of action that would be widely approved. The Commission are often criticised for not closing a larger number of branch and secondary lines; yet when after careful study the decision is reached that a particular line ought to be closed, local opposition is frequently well organized and strong protests are made. It is, however, noteworthy that those who protest are practically never able themselves to offer a solution to the problem of securing enough traffic to make the line self-supporting." The last sentence is directly applicable to much of the opposition to any processes designed to relieve the Commission of responsibility for unremunerative waterways. However, abandonment is, in most cases, not the proper solution, and it is hoped that the Commission will be successful in transferring such waterways to other bodies, and thus not evade its responsibilities to the nation for the preservation of these relics. The Report is somewhat more explicit in the extracts which immediately follow, and the Commission deserves every sympathy in having to show a deficit, meanwhile, on this account.

So far as Inland Waterways are concerned, there are long uneconomic stretches of no importance in the sum total of the country's trade, mostly the narrow canals. The present pattern of trade is not favourable to canal traffic. Shortage of goods results in need for more rapid transport, and the inherent slowness of canal traffic may be weighing more heavily against the canals at this time than would normally be the case. However that may be, it is almost certain that various stretches of the existing canals should be closed to navigation, and it is unfortunate that the requisite procedure entails much delay. The Commission are considering whether they can make proposals for transferring waterways no longer required or justified as part of their transport system to other authorities more concerned in their continuance.

The working results of the Inland Waterways—Other than carrying Operations show a deficit of £154,000 on the year's working. It is estimated that the deficit on the little used or unused canals is of the order of £100,000 per annum, and the Crinan and Caledonian Canals, which were transferred from the Ministry of Transport, showed a deficit of £45,000 during the year. These two factors alone account for almost the whole of the loss on the Commission's waterways, after charging abnormal maintenance to the Abnormal Maintenance Account.

RAIL, ROAD AND INLAND WATERWAYS.

Progress was made in the co-ordination of various activities of the Railway, Road Haulage and Docks and Inland Waterways Executives.

In July the Commission issued a Statement of Policy on the Integration of Freight Services by Road and Rail, and in October a Supplementary Statement was made covering Inland Waterways. The main theme of the two Statements was that rail, road and inland waterways services were to be developed as complementary to each other and were not to be regarded as rival forms of transport.

The traffics for which each form of transport is considered to be specially suitable and efficient were listed and that for Inland Waterway Transport is as follows :—

(i) traffic imported and for shipment in the ports connected with the inland waterway system, particularly in those instances where overside delivery from ship to barge, or vice versa, takes place ;

(ii) traffic which can be carried from point to point in barge loads ;

(iii) traffic conveyed to or from waterside premises ;

(iv) petroleum and liquids in bulk ;

(v) traffic requiring bulk movement and storage in the warehouses of the Docks and Inland Waterways Executive ;

(vi) trunk haul to river or canal waterheads with subsequent delivery by the Road Haulage Executive.

CANAL CARRYING.

The decrease of £9,400 in operation expenses is due to decreased trade and the transfer of road vehicles to the Road Haulage Executive.

Maintenance expenditure shows little variation from the previous year and a sum of £34,100 representing arrears of maintenance, was charged against the Abnormal Maintenance Account.

British Transport Commission—*continued*

INLAND WATERWAYS: OTHER THAN CARRYING.

The traffics on the waterways were adversely affected by :—

(a) floods in the early part of the year which caused some interruption of traffic.

(b) the temporary closing, pending reconstruction, of certain power stations to reception of coal by water.

(c) the restriction of coal exports during the latter part of the year which affected the traffic to the ports.

Nevertheless, the tonnage of traffic originating increased by 476,000 tons (4.2%) and the net ton miles by 3,085,000 (1.6%).

Tolls and dues have increased by £56,000. This figure, however, does not represent the true increase in 1950, because the 1949 comparative figures include receipts from the Lower Ouse Improvement, the operations of which were transferred during the course of the year to the Humber Ports. It is estimated that the receipts included under this head for the year 1949 amounted to £25,000, and but for this traffic the increase in the tolls and dues would have been about £80,000. This increase is accounted for mainly by the revised charges which came into operation on 15th May 1950, but a part of the improvement is a reflection of the increased traffics handled during the year. There was a fall of £18,000 in warehousing and other rents, mainly due to the inclusion in the 1949 accounts of a sum of £17,500 in respect of arrears of water rents. There was a drop of £21,000 in Miscellaneous Receipts, which arose mainly through a decrease of gravel sales in the North Eastern Division, and the transfer in all Divisions of certain motor vehicles and road delivery services to the Road Haulage Executive.

The working expenses show little variations from those of the previous year, though actual maintenance expenditure increased by about £254,000 mainly due to the overtaking of arrears. During the year a sum of no less than £376,000 was charged to the Abnormal Maintenance Account under this head. The bulk of this excess expenditure occurred in the South Western Division, where a heavy dragline dredging programme was carried out in the Midland District on the Birmingham Canals.

WATERWAYS TRANSFERRED DURING 1950.

The following waterways were taken over from the Railway Executive on 19th June :—

Fossdyke Navigation,
Witham Navigation,
Stourbridge Extension Canal,
Forth and Clyde Canal,
Union Canal.

WATERWAYS ADMINISTRATION.

Close liaison has continued with other Executives at all levels, and this has been extended by the establishment of Headquarters and Divisional Integration Committees which were set up following the issue of the Commission's Statement of Policy concerning the spheres and integration of rail, road and inland waterway transport.

The Executive have been associated with the Railway and Road Haulage Executives in the establishment of joint organizations for dealing with enquiries relating to rates, services, etc., at a number of towns, including Leicester, Northampton and Stourport-on-Severn.

Frequent meetings on matters of mutual interest have been held with the National Coal Board and the British Electricity Authority.

WORKS AND MAINTENANCE.

Good progress has been made in overtaking the arrears of maintenance which accumulated during the war years, and programmes of development have been adopted for certain of the main waterway routes, notably :—

RIVER SEVERN—

It has been decided to improve the channels so as to enable suitably constructed craft of 400 tons capacity to navigate to Worcester when fully loaded ;

The construction of a quay wall at Diglis Basin, Worcester, to accommodate the increasing number of petroleum-carrying craft has been started ;

Works contemplated above Worcester would permit existing craft to load to the maximum capacity of 150 tons.

RIVER TRENT—

This navigation suffered in 1947 from floods, but by combining the dredging resources of the Executive an improved channel to a general minimum depth of 5-ft. has been provided;

A contract has been let for the reconstruction of Newark Town Lock, and discussions are proceeding with the River Trent Catchment Board with a view to the elimination of Holme Flood Lock near Nottingham. These two locks are of smaller dimensions than the other locks between Hull and Nottingham, which can accommodate four standard Trent craft or one large petroleum tank barge, and when the scheme is completed there will be a considerable benefit to navigation.

Orders placed during the year for new plant and equipment included a floating suction discharger for the River Severn and a bucket dredger for the River Trent.

Many of the narrow canals were in urgent need of dredging, bank protection and improved water supplies, and an extensive dredging programme was carried out during the year, and is continuing, on those sections where traffic is still moving in large quantities. In the Midland District of the South Western Division alone 600,000 tons of silt were removed during 1950, as compared with the previous dredging output of 40,000 tons per annum.

The greater navigational depth has already resulted in craft on some routes increasing their effective carrying capacity by as much as 20 per cent. Steady progress is also being made with bank protection by steel piling.

TRAFFIC ON THE WATERWAYS.

Notwithstanding widespread floods which occurred in the early part of the year and caused some interruption of traffic, the total tonnage of traffic which passed over the waterways during the year was 11,802,000 tons, an increase of 476,000 tons (4.2 per cent.) compared with 1949. The increase was spread fairly evenly, coal being greater by 4 per cent., liquids in bulk by 5.1 per cent., and general merchandise by 4 per cent.

Traffic carried in Executive-owned craft amounted to 1,052,000 tons, or 9 per cent. of the total. A number of additional carrying craft were brought into service and orders placed included two self-propelled vessels of 175 and 300 tons capacity respectively, for use on the Severn.

The modernization of terminal facilities and the provision of cranes and other equipment for handling traffic have proceeded.

About half the tonnage of traffic on the waterways consists of coal, of which the bulk passes to power stations or to ports for shipment. Liquids in bulk, principally petroleum, continued to show promising signs of expansion, and there was some revival of general merchandise. There was a deficit of £93,795 on the carrying business, but an amount of £144,141 accrues to the Executive as toll payments in respect of this business.

WAREHOUSE AND ESTATE MANAGEMENT.

The warehouses on the waterways have in the main been filled to capacity, but the decline in the tonnage of goods stored in the open is still pronounced. Attention has been given to the improvement and reorganized operation of certain warehouses, particularly in the Midlands.

Property rents and charges for water have been increased whenever reasonably practicable. This has entailed much work in the review of old records and agreements, some of which have long outlived their economic justification. New leases have been negotiated and numerous properties no longer required by the Executive have been sold.

Arrangements have been made with a number of local Highway Authorities for the transfer to them, on terms, of the responsibility for the maintenance of bridges which formerly rested with the Executive.

CHARGES.

An addition of 16⅔ per cent. to the statutory charges for facilities or services provided on the inland waterways was authorized by the Minister and became effective as from 15th May, and increases were also made in the non-statutory charges G.L.H.B.

Port Development in the United Kingdom

Review of a Century of Enterprise and Achievement

By ROGER CHARLES

(continued from page 95)

THE HUMBER PORTS

The Humber is the third noble river to which the celebrated chronicler of the 12th century, Geoffrey of Monmouth, referred, with the Thames and Severn, when he wrote that Britain "stretcheth forth as it were three arms whereby she taketh in the traffic from oversea brought hither from every land in her fleets."

Kingston-upon-Hull, to give Hull its proper title, makes its first entrance on the stage of history in 1160 under the name of Wyke-upon-Hull when the monks of Meaux were granted a charter. Although the Domesday Book contains no reference to the place, under any sort of name, it is quite clear from other records that it was a considerable port within the hundred years which followed the compilation of the famous Book.

Hull derives its name from the river Hull, a tributary of the Humber, and was so called in the 13th century documents. Edward I changed the name to Kingston-upon-Hull on granting a charter in 1299 making the town a free borough with a right to hold two weekly markets.

As an English port Hull was sixth in importance at the commencement of the 13th century, a position which its administrators have considerably improved upon in recent times. Its principal import was wine and its chief article of export, wool.

In 1382 the port consisted solely of that portion of the river Hull now known as the Old Harbour and it was this port which Richard II granted to the Mayor and burgesses. Later, Henry VI empowered the civic authorities to elect an Admiral of the Humber and this office is still associated with the Lord Mayoralty of Hull in similar manner as the title of Admiral of the Port of London is claimed by the Lord Mayor of London.

Earlier in this article it was mentioned that, of all the ports in England, Hull alone had no legal quays established in the reign of Queen Elizabeth. The reason for this is not clear, and some 200 years later, the Commissioners of Customs reported on the necessity for these quays in order to combat pilferage and illegal practices. In common with many other ports, these hindrances to efficient port working and the steady increase of trade, turned men's minds to the construction of docks, and in 1773 the Dock Company at Kingston-upon-Hull was established and soon embarked upon the construction of Queen's Dock which was opened in 1778 at a time when the total tonnage of shipping using the port was about 100,000. The Humber Dock followed in 1809 and the Prince's Dock about twenty years later.

The threshold of the period under present review is thus reached and is marked by great port activity, for between about 1830 and 1883, the Railway Dock, Victoria Dock, Albert Dock, William Wright Dock and the St. Andrew's Dock were all built.

Hull, of course, is a railway port and it was in 1840 that the first rail connection was made when the Hull and Selby Railway was opened. Forty years later the Hull and Barnsley Railway brought the port into direct communication with South Yorkshire and the railway company then constructed the Alexandra Dock.

In common with several other ports, private enterprise in Hull found the working of a dock undertaking an onerous business, and in 1893 the Hull Dock Company found it expedient to dispose of their dock undertaking to the North-Eastern Railway Company. This Company and the Hull and Barnsley Railway Company joined forces to build the King George Dock which was opened in 1914.

Thus it was that the docks of Hull all came within the orbit of railway working in 1893 and have remained so ever since. On the passing of the Railways Act 1921, the London and North Eastern Railway Company took over the dock undertaking and have been responsible for many improvements to the dock and riverside facilities.

The water area of the docks to-day is over 200 acres with twelve miles of quays and riverside accommodation extending over seven miles. Modern cargo handling appliances have been installed to facilitate the transit of the large tonnage of goods dealt with in the port, and warehouses have been built to house grain, seed, wool and general goods.

Conservancy difficulties in the Humber have been always present owing to its geographical position, for the banks of the river were frequently subject to inundations in the early years of the port's history. The Commissioners appointed to deal with this problem raised the road about 6-ft. above its ordinary level but owing to the subsequent neglect of flood prevention duties, the Mayor and Commonalty, in 1359, decreed that all their lands outside the city walls should be let free to such persons who would undertake to maintain the banks of the Humber.

The Hull Trinity House was founded about the same time and later assumed the duty of buoying and lighting the channels in the Humber and licensing pilots, the latter duty being taken over subsequently by the Humber Pilotage Commissioners. In 1908, however, the Humber Conservancy Board was formed under Act of Parliament and assumed all these important functions. The new Board obtained jurisdiction over the River Trent below Gainsborough and the whole of the Humber from the confluence of the Trent and Ouse to the sea and their pilotage authority, in addition, includes the waters of the Ouse as far as Goole.

The construction of training walls at the confluence of the Humber, Ouse and Trent is a very important engineering undertaking carried out in recent years. This work was completed by co-operation between the Conservancy Board and the Aire and Calder Navigation who, until taken over by the Docks and Inland Waterways Executive of the British Transport Commission in 1948, were the conservators of the Lower Ouse.

The fishing industry is one of the features of this port, over 300 trawlers, all locally owned, being normally engaged in this business which is centred on St. Andrew's Dock.

GRIMSBY

This ancient port was once threatened with death by siltation but by the enterprise of some of the principal landed proprietors of the late 18th century the Grimsby Haven Company was formed to reorganise the port facilities. A dock with a water area of 15 acres was built and opened in 1800.

The Manchester, Sheffield and Lincolnshire railway was opened in 1846. This railway company, and later the Great Central Railway Company, were largely responsible for inaugurating the dock system of Grimsby.

In 1852 the Royal Dock was opened, the first fish dock in 1856 and the Alexandra Dock, an extension of the first dock, together with a cutting to the Royal Dock (Union Dock) were also constructed. No. 2 Fish Dock was opened in 1886 and extended in 1900 and the new No. 3 Fish Dock in 1934.

The total area of the docks is about 500 acres, of which 138 are water, there are six miles of quays and warehouse accommodation of over half a million square feet, in addition to extensive open storage accommodation.

In addition to fish, dealt with at the specially provided Herring Market with its covered sale ring, Grimsby's imports include timber, woodpulp, Danish provisions, fresh fruit and vegetables while steel, basic slag, dry and salt fish, and heavy shipments of coal flow outwards from the port.

IMMINGHAM

Immingham dock was built by the railway company to relieve the pressure on Grimsby due to increasing trade and to accommodate the larger size of the ships using the Humber.

Port Development in the United Kingdom—continued

The dock is five miles from Grimsby and the site was selected by reason of the fact that the main channel of the Humber flows close to the shore at this point and it was possible to construct a deep water dock with 28-ft. at M.L.W.S. The dock was officially opened on 22nd July, 1912.

GOOLE

This port is situated 9½ miles above the confluence of the rivers Trent and Ouse, about 28 miles from Hull and 50 miles from the North Sea and thus is one of the most inland ports of this Kingdom.

Late in the 17th century the cloth merchants of Leeds and Wakefield desired a waterway to cheapen the transport of their wares to Hull and at their instigation the Aire and Calder Navigation was formed in 1698 for the purpose of improving the navigation of these Yorkshire rivers. It was this body who built the first two basins or docks at Goole at the termination of their new canal. In 1848 the Railway Dock was added, the Aldam Dock in 1883, the Victoria Dock in 1888, the Stanhope Dock in 1891, the West Dock in 1912 and the South Dock in 1926.

In 1848 the Lancashire and Yorkshire Railway Company made Goole their terminus and in 1863 the North Eastern Railway completed its line from Doncaster to this inland port.

The Corporation of the City of York were, at one time, administrators of the Ouse between Goole and the Humber, but in 1884 the responsibility was transferred to the Aire and Calder Navigation, who removed obstacles to navigation by means of training walls thus strengthening and deepening the channel to the point where their jurisdiction ended and that of the Humber Conservancy Board began.

The port now comprises eleven docks and timber ponds and five entrance locks the latest, the Ocean Lock, being opened in 1938.

A distinctive feature of the port of Goole is the method of transporting coal down river on floating "trains." These "trains" are made up of 19 large steel compartments or tanks each 20-ft. long by 15-ft. wide and 8-ft. deep and are loaded with about 40 tons of coal each. The compartments are chained together and are towed, behind a headpiece similar to the bow of a ship, to Goole.

In the year ended 31st December, 1950, nearly 12,000 vessels entered the Humber ports representing a total of nearly nine million net register tons

Aerial view of Hull Docks.

THE SOUTH WALES PORTS

Strung out along the south coast of Wales are the ports of Newport, Cardiff (including Barry Dock and Penarth), Port Talbot, Swansea and Llanelly, all of which are on the fringe of, or impinge on, the coalfields, and therein lies the secret of their existence.

With the exception of Llanelly, these ports once belonged to the Great Western Railway Company but have now been absorbed into the organisation of the British Transport Commission; the port of Llanelly is administered by the Llanelly Harbour Trust.

NEWPORT

On the west bank of the river Usk stand the remains of what was once a strong castle; a mute testimony to the strategic importance of Newport during the middle ages.

It was not, however, until the early 19th century that the town began to develop, largely owing to the coal trade but also to the

Port Development in the United Kingdom—continued

concentration of heavy industries near at hand.

The opening of the Monmouthshire canal began the industrial history of the town and the construction of the tramroad from Sirhowy and the Monmouthshire Railway considerably assisted.

In the Bristol Channel the tidal range is one of the highest in the world, as much as 45-ft. at Spring tides having been recorded, thus any port development must of necessity include enclosed docks.

Since the old Town Dock, originally completed in 1802, outlived its usefulness and has now been filled in, it will be seen that the main port development has occurred during the century under present review.

The dock accommodation comprises the Alexander North and South Docks and in addition there are two large Timber Floats running parallel to the North Dock.

It was in 1875 that the North Dock was opened, approximately 29 acres in extent. The west side of the dock is well equipped with coal hoists and the general cargo quays are on the east side.

The South Dock was completed in three stages. About 20 acres, adjacent to and connected with the North Dock by a cutting, were opened in 1893, a further 48 acres in 1907 and the remaining 28 acres just before the commencement of the First World War. A magnificent lock, 1,000-ft. long and 100-ft. wide, is the principal entrance to these docks, which together form a huge letter L conforming to the configuration of the river and also reminiscent of the shape of the Millwall Dock in the Port of London.

Hydraulic and electric cranes have been installed in these docks and range from 3 to 30 tons capacity. It is natural that particular attention should be paid to coal handling equipment at Newport. Sixteen modern hoists, some having a lift of more than 70-ft. above water level, are available, and of this number 13 can deal with 20-ton wagons. Anti-breaking equipment is provided, and many miles of sidings have been laid down for the specific purpose of accommodating loaded wagons awaiting shipment, together with excellent feed roads to the hoists; all of which factors contribute to Newport's position as one of the principal coal-loading ports of the world.

CARDIFF

In view of Cardiff's present eminence among the coal-shipping ports of the world it is interesting to recall that in 1782 the local collector of Customs reported that "we have no coals exported from this port, nor ever shall, as it would be too expensive to bring it down here from the internal part of the country." This pessimistic view was no doubt due to the collector's appreciation of the fact that the export of coal from the Tyne was already a well-established trade at that time.

Although some coal was brought down the Glamorganshire Canal after its opening in 1794 and a dock of 17 acres in extent constructed at its terminus in 1798, the present development of Cardiff really dates from the building of the West Bute Dock in 1839 and the construction of the Taff Valley Railway. Brunel, the famous engineer, laid out this railway which began to operate in 1836.

John, 2nd Marquess of Bute, was largely responsible for the dock development; he is said to have contributed £350,000 of his own money to the construction of the West Bute Dock which has an area of about 20 acres, an entrance lock 45-ft. wide and a total length of quayage of 8,950-ft.

The increase in the trade of the Port of Cardiff secured its independence, for in 1840 its limits for Customs purposes were defined. They extended from the Romsey estuary to Nash Point so that technically the Port of Cardiff includes Barry and Penarth as well as Cardiff proper.

The South Wales Railway to Cardiff was opened in 1850 and this addition to the railway facilities of the district gave a decided impetus to the trade of the port that further dock accommodation became necessary. The Marquess of Bute died in 1848 but the trustees of his estate commenced the construction of the East Bute Dock in 1851. The new dock was 46 acres in extent and was opened in 1855.

Yet another railway, the Rhymney railway to Cardiff, was completed in 1858 and two years later the shipments of coal and coke had risen to 1,796,000 tons as against 4,562 tons in 1839.

The Bute Trustees, however, were not content, and in 1864 sought powers to build three more docks. Their scheme was not approved, but under a modified submission the building of the Roath basin, of 13 acres in extent, was permitted. This basin was opened in 1874 and under an Act of 1886 the Bute Docks were vested in the Bute Docks Company. The Roath Dock itself was built and brought into use in 1887, after the passing of a substituted Act of Parliament.

Enclosed docks had by this time proved themselves in various parts of the country and the various dock promoters were able to use the experience of the pioneers of this engineering enterprise.

In South Wales the Taff Valley Railway Company entered into competition with the Bute Trustees by building, in 1865, a dock 26 acres in extent at Penarth on the other side of the estuary of the river Taff. Further independent development took place at nearby Barry when in 1884 a group of colliery owners, determined to secure an alternative port to Cardiff with the facilities of which they expressed dissatisfaction, obtained Parliamentary powers to build another dock. Barry Dock No. 1, 13 acres in extent, and a basin, now known as Barry Dock No. 3, were opened in 1889. No. 2 Dock was opened in 1898 and the system was completed by 41 acres of timber ponds and three large graving docks.

1894 was a significant year in the port's history. Traffic had increased to a volume of nearly ten million tons a year and the Bute Dock Company considered another dock was necessary. In that year the name of the company was changed to that of the Cardiff Railway Company and under the new name authorisation was given to execute new works, including railways, to improve the commmunications with the coal fields.

Ever since enclosed docks established their practicability the Royal Family have signified their approval of this form of enterprise by allowing their names to be given to new docks and very frequently opening the new works themselves. Cardiff was no exception, for in 1907 King Edward VII visited the port and opened the Queen Alexandra Dock. A fine addition to the port's facilities, it has an area of 52 acres, 9,315-ft. of quayage and an entrance lock of 850-ft. long and 90-ft. wide.

1921 saw the passing of the Railways Act and the docks passed to the administration of the Great Western Railway, those at Cardiff itself, however, retaining the name of the Bute Docks, thus perpetuating the name of the man and his family who did so much to develop the port's facilities.

PORT TALBOT

This port, with which Briton Ferry is included for Customs purposes, began its career with the opening of the old Port Talbot Dock in 1837 by the Company of Copper Miners. The Port Talbot Railway and Docks Company became the owners after their incorporation in 1894 and they constructed a new dock which came into operation in 1898. Thus Port Talbot is relatively new among the South Wales ports, and yet, in another sense is a pioneer among them, for Port Talbot was the first port on the Bristol Channel to use electric belt conveyors for the shipment of coal.

The total water area of the docks is approximately 90 acres, of which 67 have a minimum depth of 27-ft. 6-in. The entrance lock is 450-ft. long and 60-ft. wide.

Although coal is the principal commodity dealt with at Port Talbot, facilities are provided for general cargo. Hydraulic cranes, transporters, transit sheds and railway sidings exist along the 3,550-ft. of quays to ensure the expeditious despatch of ships.

SWANSEA

There are few who would disagree that so far as first impressions are concerned it is better to approach Swansea by sea than by railway. The great curving line of the shore from Mumbles Head to Sear Point, backed by hills, offers fairer prospects than the black industrial regions observed from the train window.

Swansea's fine natural harbour encouraged shipping in the 12th, 13th and 14th centuries, but it is due to the black industrial hinterland that the port owes its commercial prosperity.

Port Development in the United Kingdom—continued

In the middle of the 18th century coal had begun to be worked extensively, being brought to a wharf on the backs of mules and later by means of a private canal.

The Common Quay was on the west bank of the River Tawe and all incoming ships had to lie on the river bed or across the river in Fabian's Bay, a natural tidal inlet.

Harbour Trustees were appointed in 1791 and were responsible for deepening the navigable channel and constructing the piers. The first record of a dock is in 1789 when a small dock, named Port Tennant after its owner, or the Salthouse Dock, was made near the east river and continued in use until 1880. The North Dock was formed in 1882 by dockising part of the River Tawe, but this in its turn was closed and only the basin, which has a water area of 2½ acres, is now available for traffic and is principally used by grain ships.

A private company obtained powers to build the South Dock but these were transferred to the Harbour Trustees in 1857 who completed the dock in 1859. Equipped with two coal hoists, 12 hydraulic and electric cranes of 1½ and 2 tons capacity and 5 transit sheds with a total floor space of over 80,000 square feet, the South Dock is extensively used by the smaller type of craft frequenting the port, including a fleet of fishing trawlers.

The larger docks are the East, or Prince of Wales Dock, opened in 1881, and the King's and Queen's Docks, which were opened in 1909 and 1920 respectively, and were constructed on the old foreshore to the southward of the Prince of Wales Dock in the lee of the great sea embankment.

Most of the largest ships using the port are dealt with at the King's Dock which has 70 acres of deep water and is well equipped with coal hoists having lifts up to 60-ft. above quay level and with cranes varying from 2 to 70 tons capacity.

The last dock to be built in South Wales was the Queen's Dock at Swansea in 1920, which is devoted almost exclusively to the bulk oil business.

BELFAST

In ancient Belfast the Chief Magistrate was once known as the Sovereign. That title was used in 1613 when, by a Royal Charter, Belfast was incorporated a borough and the Sovereign, twelve burgesses and Commonalty were given sanction to establish a wharf or quay within their administrative area upon the bay or creek of Belfast. Moreover, all merchants and other liege subjects were instructed to use the quay for loading and discharging ships and to pay the usual customs and duty.

The first quay was built at the confluence of the Rivers Fearsat and Lagan but no records of the date of construction exist. It is presumed to have been built as a result of the original charter but it is quite definite that it was made a legal quay in 1662.

Belfast was one of those ports already referred to which suffered from careless usage particularly in the matter of taking and discharging of ballast. In consequence, the Irish Parliament passed an Act in 1729 " for cleansing the ports, harbours and rivers of the City of Cork, and of the Towns of Galway, Sligoe, Drogheda and Belfast, and for erecting a Ballast Office in the said City and each of the said Towns."

The Corporation of Belfast could do little to implement the intentions of this Act beyond supplying the ballast and keeping the channel clear, and a further Act was passed in 1785 repealing the provisions relating to Belfast and constituting a new Body, distinct from the Corporation, to manage the Port. This new Body became known as the Ballast Board.

Although this Board showed some initiative in building the first graving dock, now known as No. 1 Clarendon Graving Dock, further controversy led to the passing of yet another Act to rectify mistakes of the past. A new Board was constituted but continued to be known as the Ballast Board and in 1826, during its term of office, No. 2 Clarendon Graving Dock was completed.

The Belfast Harbour Act of 1847, however, began the modern phase of development. This Act repealed all previous legislation and established the Belfast Harbour Commissioners who soon set

Port of Belfast.—View showing Spencer Dock (foreground), Dufferin Dock (right), York Dock (left) and Victoria Channel beyond.

Port Development in the United Kingdom—*continued*

about improving the port. The navigable channel was straightened and deepened and named the Victoria channel.

At the end of 1851 the new Commissioners were able to report the completion of extensive improvement works including the extension of the basin at Nos. 1 and 2 graving docks in order to form a wet dock now known as the Clarendon Dock. The Hamilton Graving Dock and the Abercorn basin soon followed, the Spencer and the Dufferin docks were opened on the Antrim side, and then the river itself was widened and deepened, the old Albert Quay was improved and lengthened, the Queen's Quay was built, the Donegal Quay rebuilt with new sheds on it and the Alexandra Graving Dock constructed.

The trade of the port still flourished sufficiently to warrant the construction of a branch dock out of the Spencer Dock. No sooner was this completed, in 1894, than an extension was begun and the new large dock was formally opened by the Duke and Duchess of York in 1897 and named the York Dock.

Under further Parliamentary powers the new Musgrave Channel, with its quays, was constructed and the Thomson Graving Dock built. The quays in the Musgrave Channel are the Donegal Quay, Queen's Quay and Albert Quay and form a most useful adjunct to the port's facilities since there is but a small tidal range at Belfast, the maximum rise being 9-ft. 6-in. at spring tides.

Many significant improvements have been undertaken by the Belfast Harbour Commissioners in recent years and it is possible only to mention a few.

The Dufferin and Spencer Docks have been entirely remodelled and equipped with modern sheds. In the Musgrave Channel a deep-water jetty has been built to accommodate the largest ocean-going tankers. A new dock system on the Antrim side of the Harbour was completed in two stages, the first in 1933, the second ten years later. The Rollock Dock and basin, a turning basin nine acres in extent, were included in these new works.

The Port Administration of Belfast have thus followed the great tradition of port development throughout the last century but, in addition, have recognised the necessity of linking sea with air transport by establishing the Belfast Harbour Airport on the County Down side of the Harbour.

NEWCASTLE

"It is but time wasted to carry wood to the forest, water to the river or coals to Newcastle." So runs the full quotation of which the last three words have become a popular adage. Coal has indeed been mined for so many centuries around Newcastle that few people would find difficulty in naming the commodity which has made the city a great one.

Traces of Roman mining operations have been found at Wallsend and although Wallsend coal is still famous, none is actually produced there, for many years ago the collieries were flooded, but so excellent was the quality of their produce that a good house-coal is still known as "Wallsend."

An early name of the place was Monkchester and it was not until late in the 12th century that Henry II built a new castle on the site of Pons Aelii, a Roman station, and gave it its present name.

Early records show that exports included wool, hides, skins, feathers and lead and imports, alum, pepper and ginger. The first clear reference to coal was contained in Henry III's charter of 1239 which authorised the digging of coals in the Castle Field.

The Mayor and burgesses of Newcastle were the early conservators of the River Tyne and owners of any quays that existed, but apparently their regime was too rigid to be always popular. Cromwell's Parliament received a petition complaining of oppression and injustices and called for a change of administration. In 1800 another attempt was made to create a separate Conservancy Board independent of the Corporation, but it was not until the Municipal Corporations Reform Act of 1836 created a new Town Council that the matter of the river received serious attention. A quay was constructed at Newcastle, jetties at Wallsend and the high bank at Bill Point was cut down and dredging operations commenced.

At long last, however, in 1850, after much controversy the River Tyne Improvement Act was passed which took the management of the river away from the Corporation and inaugurated the Tyne Improvement Commission.

The basis of the new Commission was composed of Tynesiders and Dues Payers. Its constitution has been amended from time to time but now, apart from two representatives nominated by the Minister of Transport, half of its members represent the riparian corporations and payers of dues comprise the remainder.

A scheme of improvements was soon formulated and the first work of importance to be carried out was the building of the North and South Piers at the mouth of the river. From the seaward end of these piers to Hedwin Streams, about 19 miles up river, is the jurisdiction of the Commissioners including, of course, the tidal portion of all tributaries, creeks, bays, havens and inlets.

The almost inevitable dock followed in 1857 and was opened by the Duke of Northumberland, whose name it bears. Its water area is 50 acres in extent and it is equipped with coaling staiths since it is principally used for the shipment of coal.

On several occasions the Commissioners considered building another dock but the North Eastern Railway Company acted first and built Tyne Dock which was opened in 1859. Tyne Dock is on the south bank of the river almost opposite the Northumberland Dock and has a similar water area.

In 1884 the second dock built by the Tyne Improvement Commission was opened by the Prince and Princess of Wales and named the Albert Edward Dock. This dock was about half the size of its two predecessors but although equipped with a two-berth coaling staith is also used for general import and export traffic.

Coaling staiths on the riverside were also built by the Commissioners at various times and by the London and North Eastern Railway Co. at Dunston, in 1893.

Although the Corporation lost control of the port by the Act of 1853 they did not lose the right to own the quays they had built prior to the passing of the Act nor yet to improve on their property, and the Newcastle Quays are now over 7,300-ft. in length. South Shields, Gateshead and Tynemouth Corporations also control quays within their respective administrative areas.

Although the annual shipping returns of the Board of Trade show the aggregate commerce of the Tyne there are three separate Custom House ports, Newcastle, North Shields and South Shields.

In 1937 the Commissioners began a comprehensive scheme of improvement by acquiring the Tyne Dock from the London and North Eastern Railway Company. This they followed by building a new quay 800-ft. long at the north-west corner of the dock, and a riverside quay known as the Sutherland Quay 450-ft. long with a depth of 30-ft. at L.W.O.S.T.

A voyage up the Tyne to-day gives the passenger a full realisation of the enterprise and energy which has gone to the making of this efficient port. If the trip is made at night it seems even more impressive, for as the ship glides between two piers, the efficiency of these great engineering works is immediately noticed, even the wind as well as the water seems quelled by these fine piers. The river is so well lighted that the salient features can be easily picked out, the Collingwood Statue at North Shields, the sinister staiths, the huge cranes and gaunt shipbuilding slipways and the impressive King Edward VII bridge flying high over the river connecting the tall banks. And as the great ships being built or repaired are passed, thoughts must go back to the *John Bowes*, the first steam screw collier built on Tyne in 1850 by Charles Mark Palmer which was instrumental in saving the sea-borne coal trade in its fight with the railways.

SOUTHAMPTON

An Act of 1803 established a harbour board at Southampton, a dock company began building docks in 1838 and the railway from London was opened in 1840. Such were the beginnings of this famous passenger port.

Natural conditions and, one might almost say, phenomena, account for Southampton's eminence. The approach to the port, Southampton Water, is both beautiful and deep, and the double tides, there is a second high water about two hours after the first, bring peculiar advantages to the port.

Port Development in the United Kingdom—continued

General view of the new Ocean Terminal, Southampton Docks.

Southampton has been a port for centuries, probably dating back to Roman times, and its primitive quays were improved during those centuries, but the main development of the port started in 1838 when the foundation stone of the docks was laid.

The docks are not enclosed owing to the comparatively stable height of the tide. They are the Outer Dock, the Inner Dock and the Empress Dock which abut on to the River Itchen and the Ocean Dock on to the River Test.

In 1933 the magnificent King George V Graving Dock was opened. This, the largest graving dock in the world, is 1,200-ft. long, 135-ft. wide and has a depth of 50½-ft. over the cill at high water, spring tides.

The London and South Western Railway Company absorbed the old Southampton Dock Company in 1892 and proved very enterprising successors, and although the port is a railway port the Southampton Harbour Board still administer the Town Quay which is used by coasting vessels.

It was most appropriate that, just under a year before the Festival of Britain was opened, Southampton should bring into use the fine new Ocean Terminal, the Port's triumphal archway, as it were, through which to usher foreign guests to the Festival.

This terminal is of modern design and extends for nearly a quarter of a mile along the east side of the Ocean Dock, where the world's largest liners are berthed.

Although strictly practical in design, the semi-circular bays at the south end give a distinctly good first impression to arriving travellers and also offer facilities for those waiting to receive overseas guests or to wave farewell to departing friends.

A technical description of the Terminal was contained in the August, 1950, issue of this journal so that nothing further need be said except that its construction acts as a most appropriate finale to a century of dock development in this country.

CONCLUSION

Reference was made at the outset of this article to the fact that there are over 300 ports in the United Kingdom, 330 would have been a more exact figure, and most of these could claim that during the last hundred years their administrators have made considerable contribution to the port developments of the United Kingdom. It is obvious that in an attenuated survey of this nature only bare indication can be given of the port development over the last century and therefore it is hoped that the administrators of the remaining ports, who quite rightly share the national pride in port development, will understand that it was quite impracticable to mention every port in these notes.

So the wheel turns it full circle, for the most apt conclusion to this article is undoubtedly another quotation from the speech of H.M. The King at the opening of the Festival of Britain. He said:

> *"With the spirit of our ancestors renewed in us we can, under God's providence, restore and expand the prosperity of which they laid the foundations. We can draw inspiration from their staunch example and confidence from the modern achievements of our own industry. We have not proved unworthy of the past and we can do better in the years ahead."*

Kandla Port Project.

It was recently announced by the Indian Government that the construction of the main harbour works at the Port of Kandla will start towards the end of this year. Surveys and investigations essential for carrying out the scheme have been completed, and tenders for the construction of the main harbour works received. The cost of the entire project cannot, at present, be estimated, but the cost of the first stage of development, which is expected to take two years to complete, varies from Rs. 3.64 crores to Rs. 8.15 crores on the basis of the tenders just received. The cost of constructing offices and residential accommodation for the staff, and roads and bridges within the port area, and the purchase of essential equipment, will amount to a further Rs. 3 or 4 crores. The present works include the construction of a quay 3,000-ft. long, a tidal basin for country craft, storage sheds and a dry dock.

Regime and Rhythm in Waterways

Are Rivers subject to Rules ?†

By HERBERT CHATLEY, D.Sc. (Eng.), M.I.C.E., F.R.A.S.

THE subject of this lecture is one which has long been in the speaker's mind and influenced much that he has written. Many others have had similar ideas, but they have remained largely dreams. Certainly no very firm or final results can yet be indicated, but thanks to the work of Kennedy, Gerald Lacey and Sir Claude Inglis*, an outline of a comprehensive hypothesis begins to appear. Many years may elapse before a fully developed theory of alluvial streams can be produced. It may be that nothing more than an approximation can be evolved. Nevertheless, it seems to the speaker that it will be useful to make an attempt to state in the widest possible terms what such a theory might be and perhaps so to guide students of river engineering towards general principles which may be useful to them, without, at the same time, uttering dogmas which may mislead.

The whole aim of the river engineer may be summed up as a desire to produce and maintain a water channel in a condition in which it is effective for the specific purpose (navigation, irrigation, drainage, etc.) as cheaply and durably as possible in spite of natural tendencies to change. Whether a waterway be artificial or natural, the conditions in which it either tends to change continuously or periodically and the range or trend of such changes determine its utility and permanence. If, as often happens, there is an effective mean condition, this is said to be its standard regime, and the oscillations about the standard regime may be termed the dominant rhythm. Speaking generally, this rhythm is ultimately solar, or perhaps lunar, in origin. There are many subtle points involved in the definition of regime. In some senses it is an artificial concept, since some change must occur, but the idea is closely approximated to in many instances.

The rules developed by Kennedy and Gerald Lacey in India for regime (not standard regime as defined above, but simply equilibrium condition in alluvium with steady flow) are not exactly true, but have formed a most important contribution to knowledge. Kennedy sought to ascertain what was the velocity in an irrigation canal in which there was neither silt nor scour. He found that the velocity in any one channel material varied as the two-thirds or similar power of the depth, and for many years this was accepted as a useful rule. Kennedy's rule, published in 1895, was modified by Gerald Lacey in 1929[1]. The latter has published other papers, especially two in 1934[2] and 1946[3], tending to show that there is a definite set of rules or norms to which natural channels tend to conform. It has also been shown by Prof. Gibson that there is a tendency for alluvial channels to follow certain scale relations of a remarkable character, which afford good support for the practice of distorted scales in river models and these agree to a considerable extent with Lacey's rules. This is rather strong evidence for them, since scale models form the most extreme instances.

Whilst Kennedy's rule was developed as a practical guide for the design of canals in alluvium, Lacey aimed to show that regime channels obeyed certain much more general rules. Since climatic conditions fluctuate irregularly and sometimes erratically, no perfect standards can apply, and it still remains to be shown how long is required to produce approximations to regime. If this could be discovered (it appears not to be impossible to do so) the whole problem would be solved for a standard alluvium subject to a regular cycle, and in practice for all natural variations except very extreme ones.

There are cases in which the channel suffers very little change due to the annual rhythm, but unless it is in rigid material, or the climatic changes are very small, this is unusual.

The cycles of the heavenly bodies (the sun and the moon) are the ultimate cause of the fluvial rhythm.

Much more important questions are those of the irregular reactions of the sun's radiation upon the surface of the earth as a whole. It is notorious that weather cannot as yet be forecast for more than a few hours, or perhaps sometimes a few days, and yet the engineer is required to prophesy the extreme weather possibilities during a century or more. Two ways may be sought. One is to assume that weather statistics occur at random and apply the so-called theory of probability to them. (It might better be called the theory of "ignorance," since it deals with the supposed laws of chance, which are only statistical). The other way is to deduce the worst which may happen, based on past experience, and consider the mathematical distribution of the conditions which make for such extremes. Both methods are highly approximate and have frequently led to the most disagreeable surprises from under estimation of costs and contrariwise have caused enormous expenditure to avoid calamities.

One of the main difficulties comes from the fact that rain is irregularly discontinuous. Whilst it is certain that in the long average run the incidence of rain follows a sine law or some such simple rule, in practice the worst conditions are dominated by a complexity of circumstances which mirrors the complexity of the universe.

What, then, is one to do? The Gaussian rule of probability offers itself as an alternative to a predicted distribution of flow according to certain assumptions. Both methods are unreliable, and both methods if followed to more or less logical conclusions involve prohibitively great expenditure. One cannot but conclude that the problem is strictly speaking insoluble, and that the practical method is to assume an arbitrary rhythm which is a reasonable maximum.

RHYTHM IN NATURE

The word "rhythm" has a rather curious history. Etymologically it means practically the same thing as regime, but owing to the fact that in music a swing from higher to lower pitch and back is a frequent feature, it has come to signify such a pulsation, and it is in this sense that it is used here.

UNITARY CONCEPT OF A RIVER

It is almost a recognised aphorism in river engineering that a river must be considered as a whole, which presupposes that there is some kind of organisation in it. Certainly there is some measure of system.

The behaviour of an alluvial river can be schematized to an appreciable degree, largely due to Lacey's work and Inglis' notes on it. The discharge varies with the distance down stream, the rate approaching the square root of the drainage area above the section referred to. The slope diminishes with the distance from the mouth, where it becomes zero, except for tidal currents. The brachistochrone, or curve of quickest descent (Bernouilli's curve), is not necessarily the curve approached, since the gravitation velocity of free flow is only a minute fraction of the total head, but it is that kind of curve. With constant silt grade and charge, the slope tends to be inversely as about the fifth or sixth power of the discharge. Silt grade being the same, the mean depth, or the hydraulic radius, various as about the one-third power of the discharge. The width or the wetted perimeter varies as about the square root of the discharge. The sectional area for constant

* Sir Claude Inglis' comprehensive paper (1949) is alluded to as B.C.R.C. (Behaviour and Control of Rivers and Canals).

[1] Stable Channels in Alluvium. No. 4736, Vol. 229, 1929-30, I.C.E.

[2] Uniform Flow in Alluvial Rivers and Canals. No. 4893, Vol. 237, 1933-34, I.C.E.

[3] A General Theory of Flow in Alluvium. No. 5518, Jnl. I.C.E., 1946-7.

† Vernon Harcourt Lecture (Abridged) delivered before the Institution of Civil Engineers. January, 1951. Reproduced by arrangement.

Regime and Rhythm in Waterways—continued

silt grade tends to vary as the five-sixths power of the discharge, and in consequence the mean velocity has a tendency to grow as the one-sixth power of the discharge, but this is often offset by the change of silt grade, so that generally speaking the velocity actually diminishes from source to mouth, the grinding action of the silt reducing the diameter of the particles and the silt grade with it. For canals, mean particle diameter tends to vary as the tenth power of the discharge (for any one particular transverse section). There is a limit to the fineness of silt, depending on its hardness, determined by the cushioning effect of the water.

All these rules are subject to correction in tidal reaches, where currents may amount to ten feet per second or even more on occasion. These effects should, however, be regarded as quite distinct from the fluvial flow and due to the alternation of positive and negative waves, which can strengthen or weaken currents and may obviously cause large changes in the estuary. A trumpet shape flare according to a logarithmic expansion gives the easiest approach to tidal current.

DEFINITION OF REGIME

A regime condition may be defined as one in which no perceptible change of state occurs, i.e., velocity, cross section, slope, stage, and silt content all remain constant. It is consistent with the presence of a moderate silt charge, provided that there is no accretion and that there is a large downstream capacity for the absorption of such a charge, and that the charge originates from a point on the stream beyond the reach in which regime is postulated.

Standard regime is mean condition of normal flow for a specified stage. If the seasonal rhythm is large, the flow may vary greatly. Between two particular stages there is almost certain to be erosion or accretion during which regime is absent, but after such erosion (or accretion) has endured for a time, regime tends to appear.

If there is meandering, regime may exist in a ghostly sense, since there may be comparative constancy in the meanders.

Much has been written as to the raising or lowering of river beds. A great deal of this is speculative and there is a good deal of confusion in the results. The example par excellence is the Yellow River in China, but it is by no means clear how far this alleged rise of bed is due to the plugging up of abandoned channels. Certainly this rise is not a major factor, but is doubtless of secular importance.* Diastrophic movements enter into the problem, which is not a simple one.

Inglis has cast considerable doubt upon the general validity of Lacey's hypothesis on account of its neglect of the silt content, but his assumptions that the laws of variation are simply according to the powers of the product of silt charge into terminal velocity are rather bold for large discharges. Lacey's hypothesis rests squarely on the belief that factors other than the slope, hydraulic radius and velocity are mutually compensatory.

KENNEDY-LACEY CANAL RULE

Kennedy's well known formula (Proc. Inst. C.E., Vol. CXIX, 1895) has been rendered somewhat obsolete by Lacey's modifications, but some doubt still arises as to the limits of the latter's validity. Unfortunately Kennedy did not adequately record the slopes of his canals, but it seems clear that by allowing for this slope effect Lacey succeeded in arriving at a rule which was more general, making the mean velocity vary as about the square root of the hydraulic radius, and eliminating the question of slope in the case of constant silt grade and moderate silt content. In recent years Blench and others have raised doubts as to the identity of behaviour of the sides and beds of canals. This undoubtedly is a serious problem.

There is no doubt that one factor in creating a discrepancy in Lacey's hypothesis lies in the fact that in the majority of natural streams the breadth greatly exceeds the depth. It may well be that in actual fact the side effects as such are practically neglected.

LACEY'S REGIME FORMULA

In his 1934 paper (Uniform Flow in Alluvial Rivers and Canals) Lacey gives his general regime formula:

$$V = 4\sqrt[3]{2g\,R^2\,S} \quad - \quad - \quad - \quad (a)$$

which purports to be independent of silt grade. R is hydraulic radius, S is longitudinal slope, V is the mean velocity, g is the acceleration of gravity. In this form the expression is independent of dimensions. It is *not* a flow formula, except for a particular state of the channel.

Inglis (B.C.R.C., 1949) makes several severe criticisms of this formula, but nevertheless it does agree rather well with many practical river problems, over a wide range of dimensions, and it is a question whether this is mere coincidence or represents a really general result.

To this, Lacey conjoins a flow formula of the Manning type:

$$V = \frac{1.346}{Na} R^{2/3} S^{1/2} \text{ in foot units} \quad - \quad (b)$$

(Na in metric units)

It should be noticed that these two formulæ are indicative of the scour or accretion of a reach not in regime since the departure of the formula b from the regime conditions requires a change of the slope or of the hydraulic radius, or of both together, to bring it back.

Lacey does not assert the entire consistency of these two rules, but this is practically implied if both are true. He rather tends to suggest that the original Manning rule is preferable $\left(V = \frac{1}{N} R^{2/3} S^{1/2}\right)$ and that the new form is really a regime rule, but the same fundamental principle applies whichever is used. Inglis considers the effects of rigid banks explain the ambiguity of the two Manning rules. Lacey also places great emphasis on the importance of the product velocity times slope, which corresponds, in his view, to the so-called "terminal velocity" with which a body descends in still water. He also maintains that the coefficient connecting the stream velocity in regime with the square root of the hydraulic radius varies as the fourth root of the terminal velocity of the particles. He terms this an equation for the velocity of bed silt propulsion.

REGIME FORMULAE DISTINGUISHED FROM FLOW FORMULAE

Kennedy and Lacey's rules are both regime formulæ which are not necessarily in accordance with mechanical principles, but merely empirical rules to connect related states of equilibrium. Lacey, it is true, seeks to find the underlying mechanical principles, but these may not be expressible in simple terms. The various flow formulæ, from the elaborate Ganguillet and Kutter, with its professed accuracy down to the simple Chezy rule, really all agree that in the main the exponent of the slope is one-half, or thereabouts, whereas the regime rule of Lacey gives it as one-third. What does this mean? The answer is rather complex. In the first place, the channel is supposed to consist of cohesionless alluvium which can change its section and slope to attain equilibrium. Secondly, it is supposed that some of the particles are in a state of steady motion. The question has been asked what will happen if the particles are wholly precipitated or, on the other hand, if the silt content is so high that the mixture is like porridge? One must suppose that in these two extreme states the conditions of Lacey do not hold, and this is precisely what Inglis has indicated to be the case.

It does not necessarily follow that Lacey's rule is valueless, and Inglis has himself shown in his "canal formula" that some such rule as Lacey's is approximately true. Inglis says that when the grade of material was kept constant and the charge varied, the exponents in the Lacey formulæ could be connected. This seems to show that in principle the Lacey formulæ are well founded, but there is little doubt that they are limited in application and not quite correct in form.

THE CONCEPT OF HYDRAULIC RADIUS

It is pointed out by Lacey in 1934 (U.F.A.C., p. 438) that the "fundamental formula" may be written in the form:

$$V = 8\ (R/V)^{1/2} \sqrt{2\ g\ RS}$$

which suggests that in channels of the same criterion $(R/V)^{1/2}$ homologous velocities bear the same ratio. In other words, provided that the ratio $(R/V)^{1/2}$ is constant C, the Chezy coefficient,

*Estimated for the Punjab at 1 foot per century. (Inglis p. 173, B.C.R.C.).

Regime and Rhythm in Waterways—continued

is also constant. This is a very remarkable generalization, maybe partially true, and may be regarded as **the closest approach to an absolute rule that Lacey has produced.**

In this connection it is worth mentioning that there is a definitely artificial aspect to the concept " Hydraulic radius ". It is, of course, the imaginary radius whose periphery is the wetted perimeter. Since the wetted perimeter is a reality and the cross sectional area is also a reality, the ratio of the two is a convenient quantity, but there is not necessarily anything absolute about it. Chezy's coefficient implies that the friction at unit velocity per unit of wetted perimeter is or can be taken to be constant, which is obviously a mere approximation based, it must be supposed, on a constant velocity. Similarly, the assumption that the water at the hydraulic radius is subject to uniform friction is still more fallacious and is disproved by every measurement of depth in terms of discharge. That there may be, for regime conditions, an homology of velocity to hydraulic radius, or the inverse, is an interesting speculation which should be easy to test experimentally.

It seems a little improbable and it is difficult to reconcile with the observed behaviour of alluvial channels.

In some cases the actual depth is much more reliable as a criterion, as Du Boys' rule shows, but the Griffiths' theories as to the direct effects of depth are not trustworthy.

Lacey, in his 1946 paper (General Theory of Flow in Alluvium), says that Mr. Blench, " in a highly original paper, has attacked the problem from a very different angle and by the application of the Hamilton principle has confirmed equation 17."

$$[8\ (R/V)^{\frac{1}{2}}\ \sqrt{2\ gR\ S}]$$

This Hamilton principle is a rule relating to the distribution of kinetic and potential energy.

It asserts that if a system of bodies is at A at the time t_1, and at B at time t_2, it will pass from A to B by such a path that the mean value of the difference between the kinetic and potential energy of the system in the interval $t_1 - t_2$ is a minimum. (Mellor's " Higher Mathematics," p. 567.)

It normally employs the " calculus of variations," which considers the manner in which functions may change *in form* to satisfy certain conditions such as the minimum referred to.

The speaker has not seen this paper, but it is apparently referred to in Inglis (B.C.R.C., p. 131), in which, on the basis of the Blasius formula, it is stated the author found " it reduced to the Lacey V, R, S, formula." Paper 5185 (Journal, I.C.E., April 1939) also alludes to it in general terms (A New Theory of Turbulent Flow in Liquids of Small Viscosity), and the correspondence on Paper 5204 (Journal, I.C.E., Oct. 1939) also refers.

Presumably this relates indirectly to the reasoning by which Lacey deduces the modified Manning formula as being a " regime " form and equivalent to varying as $(R/x)^{\frac{1}{6}}\ (gRS)^{\frac{1}{2}}$, the quantity x representing the protuberance height. (Blench, on page 394 of Paper 5204, Oct. 1939, seems to confirm this.)

Seeing that Mr. Blench finds other reasons to disagree with Lacey (stated in detail by Inglis), the argument based on Hamilton's principle is not very convincing.

LACEY'S GENERALIZATIONS

Fig. 4 in Lacey's 1934 paper (p. 428) contains his essential data on regime, and to this should be added Fig. 1 in his 1946 paper (p. 21).

The former claims to show that the regime velocity varies as the cube root of the square of the hydraulic radius into the slope $(R^2\ S)^{\frac{1}{3}}$, and the latter that the terminal velocity (V S) varies as $(R^{\frac{1}{2}}\ S)^{4/3}$. For practical purposes the terminal velocity is expressed in thousandths, which seems a pity in a theoretical discussion, but does not at all effect the principle. This alteration is effected by increasing the slope to parts per thousand. Lacey's aim is to show that the terminal velocity is a true measurement of the silt grade squared. Regime slope is, according to Inglis' quotations, $0.000547\ f^{5/3}/Q^{1/6}$, the silt grade f being measured by the ratio $\frac{3}{4}V^2/R$, which is regarded by Lacey as a fundamental Froude or rather Newtonian relation. $SV = 0.000434f^2$ according to him and Inglis, but the latter disagrees as to the identity of the two f's except at one point.

In a letter to " Nature " (3rd August, 1946), he produced a further equation based on the above equation and a relation:

$$\frac{A}{R} = 2.66\ Q^{\frac{1}{2}}\ \text{(foot units)}$$

$$S = 2\ V^5/g^2\ Q \text{ or } 2\ V^4/g^2\ A \qquad (A = \text{Sectional area})$$

which reduces to

$$V = \left(\frac{g^2\ AS}{2}\right)^{\frac{1}{4}}$$

He claims this expression is free from the defects which Inglis ascribes to the other rules, but in fact it still depends on the fundamental assumptions that the wetted perimeter (or width) varies as the square root of the discharge, and that the velocity varies as the two-thirds power of the hydraulic radius (or mean depth) and the one-third power of the slope. In both cases it is definitely asserted that in regime conditions the silt grade is effectively eliminated. Inglis does not agree, and it is also doubtful if the exponents are quite right.

Lacey holds that deviations from these simple rules are due to " shock," by which he seems to mean the creation of irregular turbulent flow due to discontinuities of profile or cross section.

This raises an interesting question as to the necessity or otherwise of simplicity in natural laws. Whilst there is no obvious necessity for natural laws to be simple, there are such laws.

Newton's law of gravity is such a law and even in spite of Einstein's modification of it, which is rather a matter of mathematical approach than basic concept, preserves its practical simplicity to an astounding degree. There are other simple laws, but none so outstanding as this.

The question now is whether the simplicity of Lacey's rules is a delusion, or at any rate an approximation, or if it is a real tendency masked by the natural complexities.

Unfortunately the practical cases which occur are so intricate in detail that great difficulty is found in disentangling the clues. To instance one particular difficulty, the eddying in a natural stream is so involved that one may delude oneself. The meanders in a natural river are similarly perplexing.

The speaker has been led to suppose that in an alluvial stream, meanders may contribute quite fifty per cent of the irretrievably lost energy. If this is the case, and the fraction is variable, it is difficult to see how Lacey's formula can be as exact as he supposes.

Obviously, even if there is a real tendency to sub-divide the frictional energy into two equal fractions, no regularity can be expected in such sub-division, except on the basis of ideal uniformity of material. Prof. Gibson has indicated the view that the losses of kinetic energy in mountain torrents, due to shock, are still greater, but this case is not quite comparable since there may be great irregularity in such streams.

TERMINAL VELOCITY

As already mentioned, Lacey attaches immense importance to the concept of terminal velocity. This is the limiting velocity with which a particle ultimately descends in still water vertically, after an initial period of acceleration. In actual fact, unless the mass of the particle is large, the maximum velocity through the water is soon reached. The engaged water adds effectively to the mass of the particle, and this reduces the velocity through the water.

Lacey's method is to compare the product of the velocity and the slope with the terminal velocity. The slope is necessarily a small fraction (say one in a hundred or maybe less) and the velocity is, say, five feet per second, so that the product may be of the order of five hundredths of a foot per second. He writes this in the form:

$$VS^* \text{ equals } 1.60\ (R^{\frac{1}{2}}\ S^*)^{4/3}$$

where S* is 1,000 times the slope. (R and V are in foot second units.)

Obviously this pre-supposes that the water remains in more or less a constant state of charge or at least that the particles are of practically constant size.

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For small particles (diameter m less than **0.08** millimeters) the terminal velocity varies as the square of the particle diameter, but for large diameters (**0.6** millimeters and over) the terminal velocity varies as the square root. These differences are due to the fact that the resistance is viscous for small diameters and turbulent for large diameters. There is an intermediate diameter for which the resistance varies as approximately the diameter. If alum is added to the water, the particles may be clumped. VS is really the distance travelled vertically per second *by the water*, not through the water by a particle.

Whilst it may be true that there is a relation between VS and the terminal velocity of a particle (the behaviour of a particle of a given size on the wall of a conduit implies that it will be loose at a velocity which is related to that at which it " swims " in the current), this is not necessarily equal to or comparable with the silt grade, which is based on hydraulic radius and velocity, and it is not quite legitimate to compare the two.

MALHOTRA'S FORMULA

Dr. Malhotra (quoted by Inglis, B.C.R.C., p. **133**) has an interesting variation of Lacey's main formula. It is:

$$V = 18.178 \quad R^{0.6321} \quad S^{0.3426} \quad \text{(ft. sec. units).}$$

One might have thought that this was a confirmation, rather than an effective criticism of the Lacey formula, but the " scatter " is very serious, and while the average is not too bad, the dispersion presents fundamental difficulties. Inglis, as has been mentioned, makes a strong point of discrepancies which exist between the coefficient of " silt grades " according as they are reckoned by:

slope and velocity correlation, velocity and hydraulic radius correlation, hydraulic radius and slope correlation.	**See Todhunter's "Algebra," p. 241, Rule 425, 1879 Edition.**

These are asserted to differ to a measurable extent, so that the whole of Lacey's arguments are thereby vitiated or only have a very limited applicability. Some examples of the inconsistencies are shown on pages **117** and **119** of Inglis' paper. It is stated by Inglis that " in any case the fit of Lacey's formula depends on " the silt coefficient for constant velocity and radius correlation coinciding with the analogous constant for hydraulic radius and slope, and that both shall be equivalent to **1.76**$\sqrt{m}$, which is said to be " rarely found in nature, and then only in restricted lengths even in the case of canals."

In a subsequent paragraph (p. **136**), Inglis states that in the intermediate semi-viscous condition the product of the charge and the terminal velocity tends to remain constant, but otherwise does not do so. (See Inglis on " Meanders," p. **54**.) This gives a certain consistency to the Lacey theory, but not sufficient to establish it. In fact, it is clear that Inglis does not regard it as having any really general validity. (See Inglis, B.C.R.C., pp. **107-137**.)

DISCHARGE AS THE CRITERION

Although there are some elements of loss which are hard to define (Schnackenburg, in a paper on Extreme Flood Discharges given before the New Zealand Institution of Engineers in **1949**, has suggested an extreme formulæ for New Zealand rivers, $Q = 20{,}000\sqrt{M}$, which seems to be rather generally true, Q cusecs per square mile, M drainage area in sq. miles), broadly speaking discharge is the best grand criterion. Lacey has stated that the wetted perimeter varies as the square root of the discharge, but Blench and King hold that the surface breadth is a better or at least as good an argument as perimeter.

These two combined (perimeter or width and discharge) give a measure of the mean depth or hydraulic radius, so that in so far as Lacey's rule holds good, depth is also defined.

Inglis (Meanders, **1947**, Discussions and B.C.R.C., **1949**) quotes the Lacey conditions as follows: (Q = discharge in cusecs; f = silt factor) = $0.75\ V^2/R$.

$P = 2.67\ Q^{\frac{1}{2}}$ foot second units,
$f = 1.76\ m^{\frac{1}{2}}$ m grain diameter in millimeters,
$A = 1.26\ Q^{5/6}/f^{\frac{1}{3}}$,
$V = 0.7937\ Q^{1/6}/f^{\frac{1}{3}}$,
$R = 0.4725\ (Q/f)^{\frac{1}{3}}$,
$S = 0.000547\ f^{5/3}/Q^{1/6}$.

He (Inglis) maintains that these rules are seriously vitiated by changes in charge and that Lacey's variations of V with S and R are not wholly independent, as he supposes (thence f is not, in Inglis' view, a single valued function).*

However this may be, the apparent simplicity of these rules makes them enormously attractive, especially when combined with Lacey's supposed law of terminal velocity ($SV = 0.000434\ f^2$).

TURBULENCE

No very marked progress has been made in the study of turbulence beyond the development of coefficients of turbulent viscosity, which is a purely empirical procedure. One would have thought that something could be made of the spectrum of the eddies according to their periodicity, but the difficulty seems to be that they expand (losing kinetic energy but not much angular momentum) and the supply of new eddies causes a confusion which cannot yet be interpreted. Acoustic analysis might help, if turbulence is audible. Noise is made by bubbles and eddies, both of which come from periodic disturbance. The mechanism of turbulent resistance is still rather a mystery. Attempts have been made to classify different degrees of turbulence under the headings of rough, smooth or the like, but not with great success. Surface waves form a very complicating factor. Some notion of the frequency with which the system of vortices are liberated is deducible from general principles, but the rates of decay of such vortices, in which they are converted to " random " motion, are still obscure. Many years ago Mr. John R. Freeman suggested that a system proposed by Hiram F. Mills had some merits. This regarded fluid friction as a definite combination of shear ($\propto v$) and vorticity ($\propto v^2$) in varying proportions. Whether such a relatively simple solution is practical is a question. The fact that writers are still disagreed as to the use of exponential, logarithmic or even more complex forms, and as to the integral or fractional nature of such forms, shows that hydrodynamics is still in a highly empirical condition, not to say " fluid " state.

STABILITY OF A CROSS SECTION

The cross section of a stream will normally be symmetrical. Lacey (Stable Channels in Alluvium, **1929**, p. **22**) implies that the form is semi-elliptical and draws somewhat heavily on this hypothesis. All the evidence available to the speaker inclines him to favour the view that the profile is a parabola of a degree depending on the ratio of the maximum depth to the surface width.† The maximum depth is a function of the discharge and the silt factor. The side slope at the edge of the water surface is an important criterion.

These two factors, together with the surface width, determine the degree of the parabola. If the side slope is **4D/B** (D is maximum depth and B is breadth) the parabola is quadratic, but for all smaller cross slopes, or rather greater breadths, the degree is much higher and can even exceed the tenth degree.

Lacey (loc. cit) suggests that the shape of the cross section is determined by the fineness of the silt, a coarse material being shallower and wider in section than in fine material, but this seems to follow also from the angle of repose without invoking an identity of the wetted perimeter for all values of silt grade with equal discharge, which is a very hazardous generalisation, in view of the small difference between width and wetted perimeter. Blench and King have, in fact, shown that widths of symmetric sections form as good a criterion as wetted perimeters.

Lacey pushed this generalization as to perimeters to the conclusion that there was a critical velocity of about **0.882** feet per

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* Inglis gives the following rules:

$$f_{VR} = 0.75\,v^2/R;\quad f_{SV} = f_{VR}^{\frac{1}{4}} \cdot f_{RS}^{\frac{3}{4}} = 48\sqrt{sv};\quad f_{RS} = 192\,R^{\frac{1}{3}}\,s^{\frac{2}{3}}.$$

Correction factor in $v = 16\,R^{2/3}\,s^{1/3}$;

Multiply by $\sqrt{\dfrac{f_{VR}}{f_{RS}}}$. This is a measure of divergence from regime.

† Of the form $y = ax$
y = ordinate
x = abscissa reckoned from axis of symmetry
n = exponential
a = constant.

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second for which turbulent conditions failed to apply, but model practice shows that in proper circumstances will permit much lower critical velocities than this.

MEANDERING

The tendency of rivers to meander is well known, and has been dealt with by Inglis in his paper on "Meanders" to the Civils (Maritime and Waterways Division) in 1947 and his book, B.C.R.C., published in Poona (1949). Some excellent plans of meanders were produced in July, 1947, by the Mississippi River Commission, under the name of Professor Fisk (two volumes, published by the Waterways Experimental Station, Vicksburg). A great deal of study has been given to the study in recent years. A very interesting instance of meandering occurs in the Jordan, but most rivers show it to some extent. The "Meander Length" is that in which a river returns, more or less, to its original direction. Inglis has shown that this dimension, like the width of the river, depends on the square root of the discharge, although Prof. White favours a two-fifths rule. The "Meander Belt" over which meandering occurs is roughly two or three times the meander length. The natural river width is two or three times (in feet) the square root of the discharge in cusecs and the meander length is often about ten times as much.

There is some difference between the behaviour of an "incised" river which carves out a path in an existing uneven mass of alluvium and a river in a flood which shifts merely by eroding its banks. The meander belt tends to be perhaps twice as wide in an incised river, but there are some cases in which the distinction is arbitrary. The height to be eroded is doubtless the main factor.

Fargue, in 1875, has shown that there is a greater degree of stability of form to be expected in a channel having a definite curvature than in a straight channel. This is specially true if flow varies and it is probably true that a trained river keeps in better condition if it is regularly curved, but not so much as to cause large variations in depth.

MODEL INVESTIGATION

The subject of river and tidal models is well dealt with in Prof. Gibson's 1936 Vernon Harcourt Lecture, and again in Prof. Jack Allen's V.H. Lecture of 1949. It presents an extreme example of artificial regime and rhythm in a stream and to some extent an ideal method of applying the criterion of stability. For reasons concerned with the need for turbulence in the flow and the practical necessity of keeping the horizontal scale within moderate limits, it is usually necessary to have some degree of distortion. Some students think this should not exceed five times, but some success has been obtained with as many as one hundred times, anomalous as it may seem to be. In fact, the comparison of natural streams of different sizes and similar material seems to indicate that a degree of distortion is not only desirable but necessary.

If Lacey's theory is true to the extent that his formula for regime (V varies as $R^{\frac{2}{3}} S^{\frac{1}{3}}$) is practically independent of silt grade, this gives an indication as to the degree of distortion. If slopes are increased $\sqrt{y}$ times, the vertical scale being 1 in y, then since, according to the Newton Froude rule, velocities are reduced in the ratio $1/\sqrt{y}$, the product of the two-thirds power of the reduced hydraulic radius into the one-third power of the increased slope is reduced in exactly the same ratio as the velocity. This disregards the effects of distortion in altering the lengths of the cross slopes of the transverse section of the stream.

Inglis has also naturally drawn attention to the inaccuracy involved in disregarding the hypotenusal effects of distortion on the cross slopes, but he has at the same time more or less annulled his criticism by postulating that the side slopes behave differently from the bed. He also points out that the transverse slopes may not follow the same rules as longitudinal slopes. The speaker is inclined to the view that this partially washes out the criticisms of Lacey's hypotheses, making it to some degree true for wide beds. On the other hand, it does make Lacey's discrimination between the wetted perimeter and the surface width somewhat fallacious.

Doodson has severely criticised certain models because they disregard the fact that, other things being the same, bottom friction needs to be exaggerated in the same ratio as the distortion of scale if the ratio between gravity and friction is to be preserved, but it does seem to be a fact that in models there is some such exaggeration, but whether it is sufficient has still to be decided. Doodson goes so far as to indicate the success of distorted models as being adventitious, but the long series of successes with models having as much as 100 times the vertical exaggeration is hard to reconcile with this broad sweeping conclusion.

Prof. Gibson, in his Vernon Harcourt Lecture, dealt with this point briefly. His view was that it was explicable as a scale effect, the effects of friction being exaggerated by scale and distortion, and he laid stress on the fact that similar bed material gave comparable results in spite of the enormous scale reduction. This is certainly true, but it doesn't wholly explain the anomalies. Once again we must invoke the side slopes as a factor to be taken care of separately.

INGLIS' 1949 PAPER

In Inglis' masterly paper, "The Behaviour and Control of Rivers and Canals" (Poona, Central Waterpower Irrigation & Navigation Research Station, 2 vols., 1949, briefly described as B.C.R.C.), he makes a strong dissociation between "erosion" and "scour," applying the first to "bank removal" and the latter to "bed removal." The actual limits of bed and bank are hard to define. The concept of vertical pillar and horizontal roller eddies may be helpful, but even this is not quite satisfactory. The banks are not normally vertical, but this distinction does emphasize the fact that the erosion of banks is a process in which vertical accelerations occur.

There is no doubt that Lacey has not given sufficient attention to the distinction between banks and beds. Inglis, in his studies of models, has been obliged to discriminate between them, and the behaviour of models with distorted scales has compelled attention to be given to this aspect of the matter. So much is this the case that in many models it has proved necessary to apply artificial stiffening to steep banks, as such steepness has been enhanced beyond the limiting values of the angle of repose of the material.

INGLIS PAPER TO THE GRENOBLE CONFERENCE 1949

Inglis' last paper is that to the International Association for Hydraulic Structures Research, entitled "The effect of variations of charge and grade on the slopes and shapes of channels."

In this, he says "The Lacey formulæ which hold very approximately for irrigation canal channels flowing in alluvium with approximately constant discharges of between 4,500 cusecs and 10 cusecs" should be corrected for the effects of charge. He implies that when such correction is made, the "f" functions which relate the slope, breadth, depth and discharge, will not be constant and that there is a periodic rhythm in the flow conditions.

He substitutes for Lacey's formulæ expressions for slope, breadth and depth in terms of the inverse sixth, the square root and the cube root of the discharge respectively, and introduces factors for m, the effective grain diameter, X the charge of the material in movement, and V_s the terminal velocity.* Incidentally, the viscosity also appears and arbitary constants are introduced. This elaborate "apparatus," with the basic assumption that the exponential rule is rigidly correct, is hard to criticise. Inglis asserts that there is a periodic oscillation of the material between a Manning-Kutter value of n equal to 0.010 during spates, to as high as 0.025 near the head of a distributary during the subsequent easing of discharge.

TIDAL STREAMS

An appreciable change has been made by Drs. Proudman and Doodson in the views held as to tidal currents. Whereas in the

* Note—Inglis says:

$$S \propto (m. X. Vs)^{5/12}$$

$$b \propto \left(\frac{X\ Vs}{m}\right)^{1/4}$$

$$d \propto \frac{m^{1/6}}{(X\ Vs)^{1/3}}$$

$$X = \frac{\text{load buoyant}}{\text{discharge}}$$

Regime and Rhythm in Waterways—continued

past it has been customary to consider tidal currents as a wave phenomenon comparable to the propagation of wind waves in shallow water, these authors have demonstrated that the tidal currents caused by the moon (and sun) are quite incapable of the effects actually experienced, unless they are enhanced by more or less synchronous oscillation. By considering the periods in which oscillations may take place in open water, and the peculiar features of straits, together with the dynamics of the earth's rotation, they have shown that a far more logical picture can be made of tidal phenomena than was formerly the case. A wave of oscillation, as distinguished from a wave of translation, can to a certain extent be regarded as a combination of two waves of translation moving in opposite directions, which alternatively double and annul each other's motion. One of the results of this is to transform the phase of the currents so that whereas in a wave of translation the motion tends to be strongest at high and low water, in a pure wave of oscillation the motion is strongest at half tide. This introduces, most unfortunately, a complexity into tidal motions which is hard to disentangle. Whereas flood and ebb are ordinarily understood to mean rise and fall of tidal levels, they also mean to and fro currents. In a pure wave of oscillation there would not be any real ambiguity, but in waves which are to some extent translatory the results are very intricate. It may even happen that the tide is ebbing (i.e. flowing seawards) at the same time as it is rising in level, or vice versa.

SHALLOW WATER TIDES

In Doodson & Warburg's extraordinarily good "Admiralty Manual of Tides" (1941), it is explained how the differences in the speeds of propagation of tidal waves due to the varying depth of the water cause the appearance of "harmonic" constituents having periods of one-quarter of the day, one-sixth of a day, and so on. These effects are superposed upon the semi-diurnal tide, but are not negligible in shallow water. One of the simplest methods of exhibiting them is to draw graphs of the currents against the tidal levels, putting the flood velocities as positive quantities and the ebbs as negatives, so that the increase and decrease of the currents from zero is compared with the rise and fall of the water from the mean level. It will then be seen that there is a marked difference in the two "profiles." According to the Airy-Doodson rules, the velocity of the wave propagation varies as the square root of the mean depth, plus or minus three times the rise or fall of the water level*, and the velocity of the currents tends to change in the same way, so that if the mean depth is say 3 times the rise or fall of the tide from the mean level, the tidal currents may be changed 1.4 times or alternatively reduced to zero. On top of these changes is the question how far the wave may be a reflected one, and it will be realised that the currents may differ a great deal from the wave profile both in phase and in degree. Nevertheless, a great deal can be learnt from such a comparison. The bore is to a great extent an exaggeration of this effect, as may be seen from the fact that bores tend to occur when the low water depths are comparable with the tidal range.

COMBINATION OF SLOPE AND TIDE

In most tidal rivers there is a combination of slope and tide, so that, speaking very broadly, the tide and the river alternately take charge. When the sea level is low the river is more or less in full control and vice versa when the sea level is high, its effects dominate at least as far as the point at which the river slope intersects the raised sea level. In the Yangtze at the time of low stage the tide penetrates to Wuhu, 300 miles (the spring range is about 12 feet at the mouth), and even when the fresh water run off is some 2,000,000 cusecs the tidal effects penetrate about 100 miles, although actual reversal of current may not reach so far. The tide gauge at Wuhu (the normal limit of tides at low stage) is about 7 feet above the value at the entrance. As the spring tide is only about 12 feet at the mouth and the tide gauge is referred to lowest low water, this indicates that the full tidal effect is not reached but is more or less approximated to.

*Disagrees somewhat with Inglis' rules (B.C.R.B., p. 53 and 439), which favour Rayleigh and Boussinesq's expression $\sqrt{g}\,(d \pm 2h/2)$; h is wave height (range).

In the I.C.E. paper No. 5223 ("The Hydrology of the Yangtze River"), published in the Journal, April, 1940, the conditions on the Yangtze are described for the lower 1,300 kilometres. There are roughly 60 meanders in 1,000 kilometres, which extend to about 25 kms. per meander in the lower 300 kms., which is practically always tidal. The flare of the high water lines averages about 1 in 7, rising to a maximum of perhaps 1 in 1.4 at the mouth (it is given in "Problems in the Theory of River Engineering," I.C.E. Selected paper No. 71, 1929, as 1 in 14. This is a clerical error). Mr. E. H. Essex, in the discussions on the speaker's 1940 paper, compared the Yangtze with Lacey's theory, which seems to show moderate agreement in spite of the cohesive material of which the bed is composed.

TIDAL MODELS

Inglis, B.C.R.C., p. 443, remarks: "The essential difference between tidal and river models is that in the former, tidal flow —determined by $V/\sqrt{gR}$—is the major factor developing bed movement; whereas in river models bed movement is determined by slope, or more correctly, slope is determined by charge—which cannot be measured directly in a river, so has to be inferred from the river conditions, i.e., it has to be diagnosed.

"In practice, the chief difference is that river models give clearly divergent results unless the charge—which determines both the slope and the shape—corresponds with that in the prototype, whereas tidal models with equivalent values of $V/\sqrt{gR}$ appear to give approximately similar results over a range of slope and vertical exaggeration."

This is a severe criticism of the tidal model as ordinarily used. Doodson's views are analogous, although he stresses the danger of vertical exaggeration.

The flow in a tidal channel is determined by several considerations, one of the most important being the degree to which friction absorbs the tidal energy. Even this is rather misleading, since if the ebb current is more concentrated than the flood (i.e. flows in a smaller and shallower channel), the strength of that current may exceed that of the flood, especially if the ebb is reinforced by non-tidal flow. Nevertheless, the tidal friction must reduce the energy imparted by the entrance currents, so that the ebb tends to be weaker in kinetic energy of the whole moving mass if not reinforced by non-tidal flow. Within one wave length (usually many miles) the rise of the tide along the foreshores involves the temporary storage of a very considerable quantity of water and energy.

EROSION EFFECTS

There is a curious statement in the well known "The Rape of the Earth" (Jacks & White, 1939, p. 33), which says "The capacity of running water to hold soil depends on the velocity of flow and the size of the suspended particles; doubling the velocity increases the carrying capacity no less than 64 times and the size of the particle 128 times." There seems to be some confusion here. The actual effect of doubling the velocity is to quadruple the resistance to turbulent flow, and if the same number of particles is affected per square foot the total effect is octuple, not 64 times. In addition to this, there is an increase due to the fact that particles more than a certain size are not moved at all, so that increasing the velocity causes more particles to be moved. If this effect varies, say, as the square of the mutual collisions per square foot, the rate may be increased to perhaps the 32nd degree, but it may be more or less than this. The effect of neap and spring tides is interesting in this respect. In the Whangpoo (see Chatley, "Hydrography of the Whangpoo," 4th edition, p. 74) the silt content varies from 325 parts per million at springs to 80 parts at neaps (average for 19 years). The ratio of maximum spring currents to maximum neaps is about six (springs) to four (neaps) in feet per second, and the depths only differ slightly. This makes the velocity ratio rather less than the fourth power or nearly the fifth including transport. Undoubtedly the grading of the mixture enters the problem, since if all the particles were the same size, they would pass very quickly from practical quiescence to full mobility. This is, however, not a simple phenomenon, since the tides vary more or less harmonically and undergo reversal. For minute particles of less than 0.08 millimetres to which viscous

(Concluded on page 129)

Port Traffic in the United Kingdom

First of Three Articles contributed for the New Education Scheme for Port Workers

(By a Special Correspondent)

As stated in an Editorial Comment on a preceding page, study courses for Port Workers have been arranged at a number of ports in the United Kingdom, and this Journal has agreed to collaborate by publishing a series of three articles in this and the two following issues. All tutors and lecturers who are responsible for the classes, and any others interested in the scheme, can obtain further particulars and copies of explanatory notes from the Secretary, Institute of Transport, 80, Portland Place, London, W.1, or from the Editorial Offices of this Journal.

Geographical and Economic Factors which Determine Port Location

The physical background. Freedom from winds, adverse currents, fog, silt, ice, etc. Importance of wide and deep approaches and a regular tidal régime. The "hinterland" and its influence. Coastwise and inland communications. Governmental assistance to British ports.

CERTAIN definite geographical and economic features determine port location, and while these continue, the port may flourish, but if, as a result of geographical or economic change they alter, the fortunes of the port may suffer. Trade patterns differ in every case, but the causative principles remain. The decline of the ports of South Wales through decreasing supplies of coal for export, and the decline of the Cinque port of Rye through the silting of the river, are cases in point.

Shelter (in the form of a harbour) and accommodation for shipping (in the form of quays for handling cargoes) are essential features of every port, and although favourable geographical, physical and political circumstances have a tremendous influence on the capital outlay for construction and maintenance, the trade element must also be there. For example, although Scapa Flow is an excellent harbour, it is not a port, as the commercial element does not exist, and therefore there is no need for the provision of cargo facilities.

Ports attract feeder systems of railways, roads and canals, often augmented by water transport using the navigable parts of local rivers and estuaries. The newer road transport systems tended to focus themselves on port towns, particularly in industrial areas. An industrial port "hinterland" as it is termed, is at once a "consuming" as well as a "producing" area which ensures cargoes both in and out, raw materials and foodstuffs being brought in, and manufactured goods being exported either abroad or coastwise. If a circle of 50 miles radius be drawn round London, Manchester or Liverpool it covers nearly all land, thickly populated and mainly given over to industry. Taking Falmouth (an excellent harbour) as a centre, the area included in a circle of this radius would be largely sea, the little land included being thinly populated and without any major industry, except possibly china clay exports.

Sometimes, for strategic reasons, or to help a local industry, the British Government finances development works in a small port. Thus the State bore part of the costs of protective works at Newlyn (Cornwall) to assist the fishing industry. The United Kingdom Government also, by the Local Government Act of 1929, granted certain reliefs in respect of local rates to transport undertakings, including ports. This "derating," though subject to certain conditions, is nevertheless indirect State Aid. State aid for ports is common Governmental practice the world over.

Different Types of Ports with Brief Notes on Their History and Development

Nomenclature by approach (estuarial, river, sea, canal). Nomenclature by function (entrepôt, transhipment, bunkering, railway passenger terminal). History of growth and development of the principal ports of the U.K.—not more than six, with emphasis upon local port or ports.

Most of the major ports of the world to-day are sited on river estuaries in positions naturally sheltered, thus avoiding the need for expensive artificial protective works such as breakwaters, etc. Many have a long history of ocean and coastal trading. London originally was the furthest point on the Thames to which, in olden days, ocean-going vessels could sail without having to lighten. It had (mainly as a result of scouring caused by the building of old London Bridge), a deep pool close to the Tower where ships could lie always afloat. Places like Queenhithe and Billingsgate were busy spots for the handling of seaborne cargoes as early as the tenth century. Diurnal tides enabled vessels taking advantage of them to pass river shoals without fear of grounding on the way up, whilst the currents and winds experienced within the port were not dangerous. Other estuarial ports (as they are called) are Antwerp and Hamburg, which also have similar histories. Estuarial ports are those most likely to have a favourable "hinterland," especially if the estuary runs through an industrialised area, for it must comprise nearly all land.

Such ports tend to collect around them local produce markets (thus London wool, Liverpool cotton) which themselves are of great benefit to the banking, merchant and labouring communities of the town. Where a port has in course of time become the focal point of several commodity markets, with the attendant buying and selling that needs warehousing and storage facilities (usually provided in the port area itself) together with the many different operations to be performed (again in the port area often by port staffs) in order to make the goods imported available for showing for sale, or suitable for re-export, it is often referred to as an entrepôt port. This latter term, it should be noticed, refers to the place the port occupies in the mercantile system of a country or area. London, Bristol, Antwerp and Hamburg are examples of entrepôt ports.

River ports are often situated at the highest point on a river (often subject to seasonal variations in flow) to which ocean-going vessels can proceed. Manaos, 1,000 miles up the Amazon, receives ships drawing up to 24-ft.; Iquitos in Peru, 2,000 miles up, ships up to 10-ft. during "low river" and 23-ft. at "high river" periods. Lokoja, at the Niger-Benue confluence, takes vessels of 12-ft. draft during the "high river" period, when floodwaters from the rains in the catchment areas are passing to the sea. Such places are collecting centres having storehouses for raw materials brought by canoe or pack animal from inland areas, the merchandise being exported during the "high river" period. Norwich in Norfolk is a developing United Kingdom river port, used by barges and coasters.

River ports, whether their hinterland be industrialised or agricultural, are usually points whence transhipment of cargoes from sea going (or canal going) craft takes place, or where opportunity is taken to load lighter drafted or smaller craft in order to proceed to destinations further on, where possibly navigation is restricted. An example of a sea transhipment port is Rotterdam, where cargoes from ocean-going vessels are loaded into Rhine-going barges. Brentford on the Thames is a point where cargoes from large river barges are transferred to the smaller and narrower

Port Traffic in the United Kingdom—continued

craft suitable for the passage of the British canals to the Midlands. But for its being overshadowed by the larger port of London, it could properly be called a river transhipment port.

Seaports, properly so called, do not usually attract a large or diverse trade by reason of their situation. Generally, they are either fishing fleet bases or terminals for a railway or road system, the changing point for sea or land transport. They are often expensive to build and costly to maintain, due to the necessity to provide artificial works to ensure shelter from the elements.

Thus Dover, an ancient Cinque port, a United Kingdom-Continental terminal originally designed as an Admiralty base, is now almost entirely artificial, with large breakwaters to protect its packet boat berths.

Liverpool emerged as a premier port when the River Dee silted in the 16th century, relegating Chester (Liverpool had been considered a mere dependency of that town) to the position of a minor port. The colonising of the Americas and the industrialisation of Lancashire and the Midlands brought the port to its present eminence.

Manchester was formerly an inland city and was made a port in modern times by the construction of a ship canal. Before its connection with the sea the town was already the centre of a thickly populated industrial area, that essential of a flourishing port.

Special Facilities for Shipping and Discharging Cargoes

The tidal factor as it affects type and capital cost of port accommodation. River wharf or jetty.—Bulk traffic (mechanised plant layout, handling oils, raw materials and finished products from local works). Cheap first cost, and tidal range ignored, but large vessels (ocean going) must be provided with sufficient flotation alongside. Ideal for general cargo coasters. The open basin. General and bonded traffic, bulk and coaster cargoes. Medium first cost. Tidal range not to exceed 12 feet and sufficient flotation provided to be suitable for ocean going vessels. The enclosed dock. General, fine goods, and bonded traffics. Some bulk cargoes. High first and continuing costs (working of locks, maintenance of water levels, etc.). Port mechanical equipment (cranes, trucks, bulk handling appliances for special traffics—grain, bananas, etc.). Port facilities—graving docks, floating docks, passenger landing stages, etc. Port labour supply. Turn round of ship in port.

A small tidal range (i.e. difference between the high and low water levels of spring tides), a deep approach channel leading to a slow flowing and deep river or estuary with stable banks and little or no bar at the mouth, are the ideal physical characteristics for the establishment of a port.

On much of the American seaboard the tidal range rarely exceeds 3-ft. and enclosed wet docks are usually unnecessary there, but Glasgow, with a range of 12-ft., is regarded as verging on the working limit for open basins and the deep water river quays characteristic of that port. Most of the large U.K. ports have enclosed docks as well as river quays.

Quay deck and ships deck levels vary according to ships' size and, in addition, tidal variations in open basins or river, when discharging or loading vessels there, necessitates constant attention to moorings. This and the continuous adjustment (to suit altered levels) of any mechanical handling equipment used, causes much lost working time.

To overcome these difficulties, to ensure closer supervision, and assist expeditious handling of more valuable cargoes, enclosed docks are necessary.

These provide an enclosed area of water, generally maintained at a continuous level, equal to that of high water in the main river or sea. Artificial walls or quays line an area excavated into the bank, or reclaimed land may be used. A chamber or passage to river or sea, fitted with flaps or gates, closed at high tide, ensures a maintained level inside, and ships lie afloat alongside the dock walls, which carry on their tops and in the rear loading and unloading appliances, sheds, warehouses, etc. Equal water levels outside and inside are essential before a single entrance flap or pair of gates can be opened, a disadvantage avoided by the pound lock, a contrivance first employed in the 15th century in Italy. By its use of a chamber fitted with double flaps or pairs of gates, ships can pass in and out of a dock into a river or sea if the water levels are different.

The lock chamber must be large enough for the biggest vessel intended to use the dock and it may have a depth sufficient to permit deep drafted ships to enter it from seaward at low tide. The aim of a modern port is to provide locks of such depth that deep drafted vessels, after passing any shallow approach areas, may go straight into the dock via the lock, without waiting for sufficient water outside to pass them over the inner lock sill or dock bottom. Low water locking is expensive, since water lost from the dock (if the level is to be maintained) has to be made up by pumping, but delays to ships are avoided. Capital costs too, are high.

Ports in industrialised countries are nowadays expected to have deep and well-lighted approach channels, clear and straight dock quays and river wharves, good and well lighted shed accommodation, with railway tracks and quay and mobile electric cranes of modern design. Good repair facilities with graving (dry) docks or floating docks of dimensions suitable for the largest vessels using the port are also regarded as very necessary.

Skilled and unskilled labour in good supply is very essential. Before 1939 most dock labour in the United Kingdom was casual, being employed by the day or half day as work offered. Since then, however, dock labour has been "decasualised" and attendance allowances and a guaranteed weekly wage are paid to duly registered men who report for duty, but cannot be employed due to lack of work, bad weather, etc. The scheme is administered by the National Dock Labour Board.

Casual employment in the past was one of the worst features of port economy. It is mainly due to the irregularity of ship arrivals and departures, and unpredictable weather conditions (cement, flour, greenfruit, etc., cannot be handled in rain). A "pool" of labour accustomed to dock working, to be drawn upon as work and ships offered is essential, for a ship delayed in a port is not earning freights, but is an expense to her owners and must be turned round quickly. To recoup itself for capital outlay and cost of services it provides, the port charges dues on all ships using it, and also charges merchants for handling their goods. So shipowners are concerned to see that their vessels spend as short a time as possible immobilised in port. Among the essentials to provide a quick turn round in port is a good and plentiful supply of labour, ready to work a number of vessels simultaneously, using up-to-date handling equipment. Many port employers formerly endeavoured to keep a large labour force, but the size of and recruitment to the "pool" in each port is now controlled by the National Dock Labour Board, who register both employers and employees. These only are allowed to employ or work on the quays or wharves.

Certain ports, by their position or sometimes by custom, give facilities for cargoes moving in bulk, having quays fitted with special machinery solely to handle full shiploads of one commodity. Coal staiths have machinery designed to handle coal in truckloads, cold store quays, special equipment for speedy handling of perishable cargoes through transit sheds and quick delivery to land or water conveyances or cold storage. Bananas and grain in bulk call for special machinery for expeditious handling.

Bulk traffics to the United Kingdom are one way only, inwards (petroleum, grain, bananas, etc.) or outwards (coal), and the areas behind the special quays are designed to supply, or to convey away, vehicles, etc. handling the bulk commodity. To keep a quay coaling plant continuously supplied, needs considerable standage for full wagons, and a separate area for empties behind the quay, and, this renders it unsuitable to deal with, say, export traffic which needs cranes and shed storage space (to hold cargo sent down for shipment). Certain ports have their bulk handling equipment designed so that quay space is left for handling other cargoes. The result is usually an uneasy compromise.

Port Traffic in the United Kingdom—continued

There must be a considerable demand from shipowners and merchants for bulk handling facilities before a port can allocate valuable quay space to it, and to safeguard itself, the port authority often requires a fixed annual minimum tonnage to be guaranteed. Factories for processing bulk commodities are often set up on or close to the dockside, flour milling being a common example. The millers discharge grain in bulk into their granaries, the actual milling sometimes being done in the dock area. Most United Kingdom major ports have at least one quay let to flour millers, but it is sound economics for a port not to concentrate on only specialised cargoes. Some coal export ports are good examples of over concentration of one particular commodity.

Rights and Duties of Port Undertakings in Relation to H.M. Customs and Excise

The Customs Officer: Brief resumé of his function and powers. Customs examination, port health procedure, etc., on vessels entering. Customs documents for ship and entry at Custom House. Ship documents and procedure with port or dock authority. The British registry, deck cargo and load line certificates. Port dues and light dues—collection. Customs examination, port health and immigration procedure, and Customs documents and clearance of vessels outwards.

H.M. Customs activities impinge closely upon ports, affecting the handling and documentation of both ships and goods. Customs officers, in guarding the Revenue, have great influence on the movement of merchandise into and out of U.K. ports. To enable them to discharge their duties they exercise powers conferred on them by the Legislature which lays down that special accommodation must be provided for them in the dock or wharf area. Special forms and procedures have been evolved which owners or agents for ships or for goods must follow. It is in this sphere that the services of an Agent or representative at a port are valuable to a shipowner. He will be aware of all local procedures, persons to be advised of the expected date of ship's arrival, etc.

A ship arriving at a U.K. port from anywhere outside, proceeds to the recognised "Customs Examination Anchorage" to be boarded by a Customs Officer of the Waterguard Branch, often in company with the Port Health Officer (if there is one). If no case of infectious disease exists on board, the Master receives his Pratique Note (or inward Bill of Health) from the boarding officer on behalf of the Port Health Authorities. No person may land from the ship before this note is given to the Master. If a case, or a suspected case, of infectious disease exists on the ship, the Port Health Officer or local competent authority may decide to quarantine it, when the vessel must proceed to a specified anchorage and all persons remain on board for a stated period.

The Customs Boarding Officer also searches the ship for contraband, and the Master is required to produce a list of dutiable goods for ships use as stores, or in possession of members of the crew. Small quantities of such goods are allowed free for personal use. The officer, if satisfied that these items are included in the Master's "Report" (see below), seals up such stores to ensure that nothing will be used or removed whilst the vessel is in port. The Master also makes what is called a "Report" (in duplicate) giving details of ship, cargo, name of Master, port of origin, present berth, list of dutiable stores on board, details of cargo for other ports, number and nationalities of any passengers, and makes a declaration that the vessel has not "broken bulk" since leaving port of origin. A parcels list, comprising small consignments not shown on the Bills of Lading and a mails certificate has to be lodged with H.M. Customs when on board. These formalities completed, and any duty paid, the Master is handed a "certificate of inward clearance," and the ship proceeds to her inwards berth.

Ship procedure with the port or dock authority turns on the payment of port or dock tonnage dues, charges based, for U.K. ports (and in most places abroad) on the ship's nett registered tonnage. The ship's Master or Agent produces the certificate of registry, deck cargo certificates (if any) and after scrutiny by H.M. Customs, the port dues collecting officer calculates from the figures given on these documents the ship dues, according to a published scale, at so much per registered ton. Dues are normally payable on entry inwards, although by arrangement may be paid by ship's agent after her departure. Reductions are made for entering or leaving in ballast, while a vessel sheltering from weather, or a naval vessel is allowed free. Dues usually cover a period in port, on expiry of which a daily rental is charged.

Light dues are charges levied on the same basis as port dues collected in the U.K. by H.M. Customs for the Lighting and Buoyage Authority (in England, Trinity House) to defray the cost of coastal lights, navigation aids, etc. Six foreign or ten home trade voyages in one year exempts a vessel from further light dues in that year.

The Master (or ship's Agent) on receipt of orders to sail, obtains permission to ship all "bonded" (i.e. goods held in a special store until duty is paid) and dutiable stores for use at sea. These are shipped under supervision of Customs to whose officers the Master hands an "Entry Outwards" form giving details of destination, and ship's load line which the Merchant Shipping (Safety and Load Line Convention) Act, 1932, places under the scrutiny of Customs personnel. If no outward cargo is taken a "Ballast declaration" is handed over on which is entered by Customs all bonded stores shipped. After a check over and resealing of the stores brought in, and the Master has satisfied Customs that all crew engagement and discharge formalities with the local Registrar of Shipping and Seamen are completed, he is given a Jerque Note, a copy of which is sent to the Customs House.

The Master or Agent attends Customs House with Jerque Note, Entry Outwards Form, either "Ballast" or "Master's Declaration and Stores Content for vessels outwards with Cargo" form, and Victualling Bill, showing bonded and drawback (i.e. duty paid goods on which a refund may be claimed on re-export) to which Bill a "Clearance Label" is attached showing both Master's and Ship's name.

Bills of Health, issued by H.M. Customs (or Consulates of the countries to be visited) numbers and full lists of names of passengers and crew (the passenger's list signed by both Customs and Emigrant Officers) and the ship's passenger certificate (if it has one). All these papers or forms have to be produced to the Officials, who, satisfied that port dues are paid (evidenced usually by the Port Authority's Official stamp on the Master's declaration) and Jerque Note in order, the Principal Searcher signs and stamps the "clearance label." The ship is now "cleared" outwards.

Import Procedure and Documents

Customs examination and control on goods arriving. The ship's manifest. "Entering" imported goods. The bonded store and the handling of bonded goods. Import procedure with the port or dock authority. Payment of tolls and charges. The bill of lading. The responsibility and procedure for delivery of imported goods.

Customs control on goods arriving is based on a complete list, containing full description, weight, port of loading, marks, numbers, shippers and consignees' names (if known) of all cargo on board. This list is known as a Manifest, and there are two forms, viz. the Consular, for Customs purposes, and the Captain's, for use by the Shipping Company.

The Consular Manifest accompanies the Master's "Report" to H.M. Customs, who decide which items from it they will examine to determine if dutiable goods have been used in manufacture, or if duty depends upon a gravity or percentage content (say of spirits) to determine this. They may call upon the dock authority or shipowner's employees to open any cargo and take samples of goods, etc., to be sent for analysis to assist in identification and correct assessment of duty.

All packages so dealt with are resealed, and a note made on the documents of the Customs opening or sampling.

For all manifested cargo an "Entry" must be made at Customs House by the consignee or his Agent, a formality necessary even if goods are not dutiable, before Customs will allow delivery. Dutiable cargo can often be passed straight into a "bonded store" (i.e. a warehouse the owner of which has given a cash

Port Traffic in the United Kingdom—*continued*

bond to Customs to cover duty on goods stored). Such stores or warehouses have two locks on all doors, the keys of one held by Customs, the other by the Port Authority, or " warehouse keeper." Goods are held in bond at the owners' expense until "entered" and duty paid, or until transferred (perhaps still " in bond ") by approved locked transport (often under the continuous supervision of a Customs watcher during transit) to other " bonded accommodation " elsewhere, either for re-shipment out of the U.K. or packaging, etc., prior to sale. Wines, spirits, tea, etc., may be dealt with in bond, wines bottled, tea blended, etc., duty being paid when goods are delivered for sale to the home market. Payment of duty means that trader's money is held by Customs in respect of goods that may be intended ultimately for shipment out of the U.K. Goods for consumption in the country pay duty, those re-shipped abroad from " bond " do not.

Import procedure with the Port Authority turns on the Bill of Lading, a document issued by the Shipping Company for each separate consignment. It is signed by the Master and contains the conditions, etc., under which the Company carries cargo, as well as a full and complete description of goods actually shipped. (The manifest is really a list of all bills of lading, with all particulars in respect of all the cargo in the ship). Its possession by a consignee is taken as prima facie evidence of ownership of the goods named therein. The shipowner has a lien on all cargo carried for payment of freight (the cost of carriage) and the Bill of Lading for a consignment is only forthcoming when this has been paid. The Bill of Lading is then " released " (by endorsement) and handed to the consignee, who may obtain delivery from the Dock Authority after passing an " entry " for the goods with Customs and payment of duty (if any).

The Bill of Lading, being a document of title, can be pledged with a bank, or sold to another person for value, the transfer of the cargo it represents from the original importer being done by his endorsing it on the back to the new owner.

If it represents a large consignment, delivery may be taken piecemeal, the owner giving instructions for stated quantities to be delivered on production of orders bearing his signature to the Dock Authority, until the consignment is cleared. The dock authority, as public warehousekeepers, have a duty to persons entrusting them with goods to house and safeguard them, and deliver as far as reasonably possible, to the person intended. They must comply with all Customs and Bank, etc., orders not to deliver until certain conditions are fulfilled, and the law permits them a lien for charges on all cargo, which can be held until all port, etc., charges are paid, or the goods themselves can be sold and charges recouped out of the proceeds.

Export Procedure and Documents

Customs examination and control on goods exported. The shipping note. Clearing Customs. The function of a shipping and forwarding agent. The payment of port tolls and charges on goods.

Certain U.K. ports make a levy per ton on cargoes passing through them, with the object of raising funds to meet the general expenses of the port itself. " Port Rates," " Town dues," etc., are names under which such tolls are known, and they are additional to the normal port charges on goods, being incurred as goods are brought within the Customs limit of the port. Payment to the Port Authority is linked (as with light dues) to the Customs machinery for import, transhipment and export " entry " procedure, goods not being " cleared " until the " toll " is paid as evidenced by the Port Authority's stamp on the entry form.

Cargoes outwards are detailed on a " Shipping Note," a request to a shipowner from a consignor to receive certain goods, detailed description and marks, weights, values, etc., as stated on the note, for shipment to a certain port by a (usually) named vessel.

The consignor may employ a local forwarding agent to handle the goods on his behalf through Dock Authority and Customs, which latter notify the dock or wharf whether they may be allowed aboard, held against instructions, to be opened for examination, etc., in the same way as import goods.

The shipping note is sent to the Dock Authority as an instruction to load the goods, and if Customs agree they tender the goods to the ship. Where shipowners employ and pay for all stevedoring (i.e. the actual reception and stowage of the cargo on board) the Dock Authority's responsibility to the shipper ends at the ship's rail, the stevedore acting for the shipowner inboard from this point. The Dock Authority makes a charge payable by the consignor for its services in clearing Customs and placing on board. A receipt known as a " mates receipt " is given by the ship for all cargo loaded. This can be " claused " if the cargo is damaged etc., although it should agree in all respects with the particulars shown on the shipping note. This receipt is accepted as evidence that the cargo named has been placed aboard and on its lodgement with the Shipping Company, Bills of Lading are issued, covering the consignment. One copy of the Bill of Lading goes to the ship, one to the consignee abroad, and one to the consignor, and to prevent double delivery by two bills of lading being presented with the same goods at the consignee's end, each is claused to the effect that fulfilment by delivery, etc., of any one copy invalidates all other copies.

Shipping import and export documents in these days of quotas, exchange controls, most-favoured-nation agreements, and the multifarious Customs duties, are so many and varied that a forwarding agent is usually engaged to handle cargoes in and out at either end. He keeps himself abreast of all legislation bearing on the import and export of goods to the countries whose cargoes he handles, and guides his principals keeping them abreast of current developments.

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Publications Received

Port of London Guide. Edited by Frank C. Bowen. 25s. post free U.K. Coram (Publishers), Ltd., 66, Victoria Street, S.W.1.

This book, which was published early last month, will help to reduce the present difficulties of harassed industrialists, shipping agents and lorry drivers trying to ship or collect cargo in the Port of London.

This highly-complex port, spread over 69 miles of tidal river and five widely-dispersed groups of docks, presents countless problems that result in many time-wasting telephone inquiries from industries and agents perplexed by the topography of the Thames tideway. One section of the book, for instance, provides an alphabetical list of the hundreds of Thames-side wharves between Teddington and Gravesend. For easy location, each wharf has been given a key number correlated to a Table of Distances and, in many instances, to a series of gridded maps showing road approaches.

Other sections of the Guide deal with the no less confusing maze of public and private interests along the tidal Thames, and contain particulars of the different functions of H.M. Customs, the Port of London Authority, the Trinity House Corporation, the Port Health Authority, private bunkering and repair facilities, etc. Of equal value are the details given about the Port's enclosed docks, the principal shipping lines using each dock, tidal distances, navigational information about bridges, etc.

Port of Bristol Handbook. The 1951 edition of the official handbook of the Port of Bristol Authority, has recently been issued. The handbook contains details of the facilities at the City, Avonmouth and Portishead docks and among other features is a list of the overseas ports served from Bristol. An extensive list of dues on both vessels and goods is also included, and details are given of the progress being made with port improvements, including the provision of a number of cranes.

Model Studies of Apra Harbour

Carried out by California Institute of Technology in Collaboration with United States Navy Bureau of Yards and Docks

ROBERT T. KNAPP, Director.

(continued from page 86)

Investigation of Disturbances within the Harbour

LONG PERIOD WAVES

Some harbours are subjected to disturbances from long period surges (waves with periods of from 30 seconds to 60 minutes). These are sometimes productive of what appears to be inexplicable damage to waterside facilities. It was therefore decided to investigate the effect of long period surges upon the areas of usage of the Apra Harbour. A surge will rarely exceed 0.3 feet in amplitude outside the harbour; hence with extreme amplification, it will not exceed one foot inside the harbour. It does not seem likely that a vertical movement of 12 inches occurring at a period of two or three minutes (or longer) constitutes a serious problem; thus the probability is that the source of any difficulty must be the horizontal water motion associated with the surges. Since experience has shown that docking difficulties are much more pronounced for some surge periods than for others of equal amplitude, it has been suggested that the dynamic properties of the ship-mooring line system must play an important part in determining which surge periods will cause major ship motion or damage. Preliminary results of studies at the Naval Operating Base, Terminal Island, California, indicate that typical mooring installations are unaffected by surges of longer than a 6-minute period, with the most dangerous range being that from 1 to 3 minutes.

The problem arises from the resonant amplification of these long period surges within the harbour, and is complicated by the large number of modes of oscillation possible in a harbour of irregular shape such as Apra. It is possible to predict the modes and approximate periods of oscillation of a basin by consideration of the equations for shallow water waves of small amplitude, but it is not possible to compute the amplification factors, since these depend upon the energy lost in each cycle by damping, and by the fact that for a real harbour the reflecting surfaces are seldom straight and parallel; hence some of the energy is reflected out of the ideal mode of oscillation and so lost from the system. The results of such period calculations for Apra are as follows with reference to modes indicated in Fig. 44.

PREDICTED MODES OF OSCILLATION

Mode No. Fig. 44	Mode Description	Period in minutes Funda-mental	First Harmonic	Second Harmonic
1	East-west, east end repair basin to open harbour entrance	29.0	9.5	5.8
1a	East-west, east end repair basin to break-water near entrance	12.5	6.3	4.2
3	East-west, shoals or inner breakwater to open harbour entrance	15.0	5.0	3 0
3a	East-west, shoals or inner breakwater to near harbour entrance	6.5	3.2	2.2
4	North-south. Gab-Gab beach to outer break-water	4.4	2.2	1.4
5	East-west, east end repair basin to shoals or inner breakwater	5.8	2.9	1.9
6	North-south, in repair basin	3.2	1.6	1.1

The additive end correction for open ended modes has been taken as 15 per cent.

Since the horizontal water velocity depends on wave height, it is practically impossible to calculate its absolute magnitude, but it can be expressed in terms of that associated with a wave of unit height. (See p. 82, expression 5.)

$$V_{av} = 1/\pi \sqrt{g/d}$$

then for the outer harbour: d = 120 feet

V_{av} = 0.17 ft./sec./ft. of wave height
= 0.10 knots/ft. of wave height

for the repair basin: d = 45 feet

V_{av} = 0.27 ft./sec./ft. of wave height
= 0.16 knots/ft. of wave height

for the inner harbour: d = 32 feet

V_{av} = 0.32 ft./sec./ft. of wave height
= 0.19 knots/ft. of wave height.

The horizontal displacement, a, of the water particles is equal to the product of the average horizontal velocity and half the wave period, or:

$$a = T/2\pi \sqrt{g/d}$$

then

for the outer harbour:

a = 5.1 ft./ft. of wave height/minute of wave period:

for the repair basin,

a = 8.1 ft./ft. of wave height/minute of wave period:

for the inner harbour,

a = 9.6 ft./ft. of wave height/minute of wave period

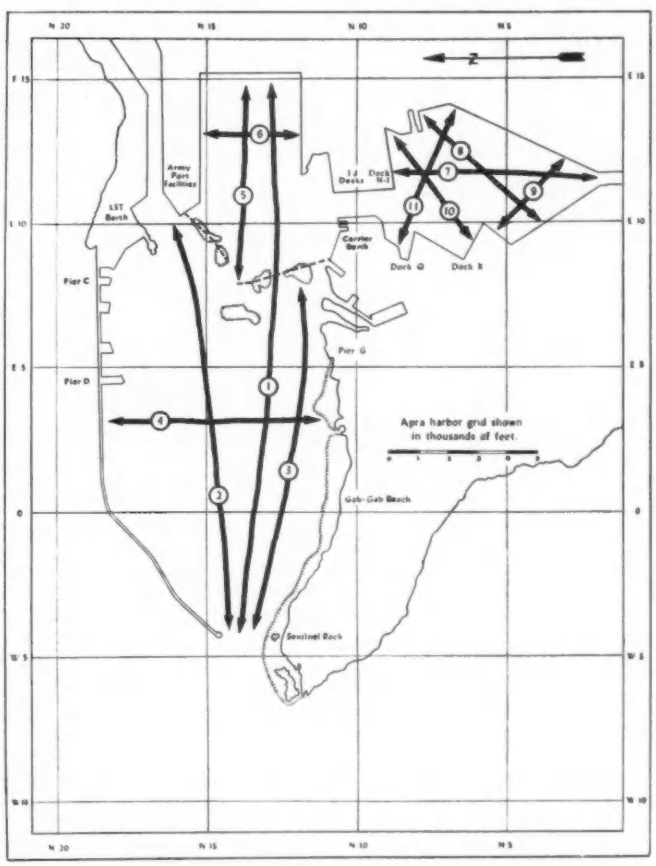
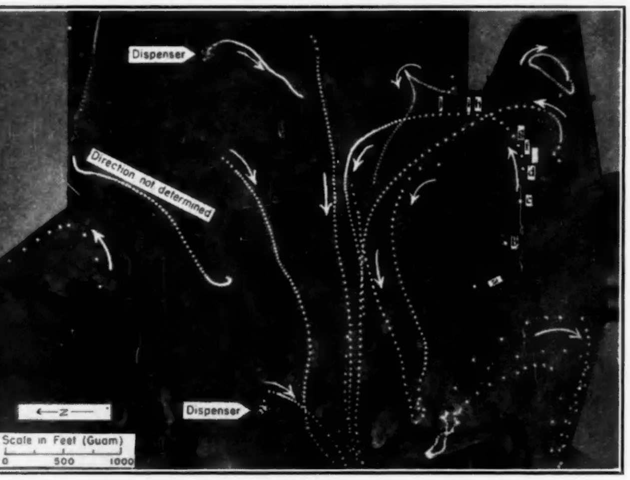


Fig. 44. Observed modes of oscillation of Apra Harbour Model.

Model Studies of Apra Harbour—continued



Interval	Distance (feet)	Time (seconds)	Speed (knots*)
a-b	457	190	1.43
b-c	383	190	1.20
c-d	276	190	0.86
d-e	106	76	0.82
e-f	101	76	0.79
f-g	85	76	0.66
g-h	370	380	0.57
h-i	85	76	0.66

$$\text{*Knots} = \frac{\text{Distance (ft.)}}{\text{Time (sec.)}} \times 0.5921$$

Fig. 45. Part of typical record of current velocities.

These expressions for the horizontal displacement and the average velocity emphasise an important characteristic of the horizontal water motion; that is, for a given wave height, the horizontal velocity and displacement vary inversely with the square root of the water depth, thus the greater the depth the less the horizontal velocity and the horizontal displacement—in other words, the protection afforded to the inner harbour by the shoals, repair basin and channel, though sufficient to decrease the vertical amplitude of the waves by 50 per cent., the effect of the surge motion in the inner and outer harbours was equally severe. This effect should be borne in mind for any evaluation of the performance characteristics of different parts of a harbour. Another point of note is that, in a progressive wave, the maximum horizontal velocity and displacement occur at the troughs and crests, whereas halfway between these two positions the values are zero. In a standing wave the opposite is true; the horizontal velocity and displacement are zero at the antinodes, or troughs and crests, and maximums at the nodes.

In actual conditions of a harbour oscillating at resonance, there will be both progressive and standing waves, thus complicating the pattern and making it difficult to predict analytically. A further point is that the horizontal velocity and displacement must always decrease near to a reflecting boundary, since there is always an antinode of a standing wave at such a boundary.

In Apra Harbour several water level measuring stations were installed. The marigrams obtained from these stations showed the existence of a prevailing 40 to 50 minute surge throughout the harbour. It should be appreciated that the lack of evidence of the existence of other surges of dangerous periods does not rule out their existence, as the small amplitudes and long periods make detection difficult, particularly in areas subjected to local " chop." The rather serious surge condition at the Naval Operating Base, California, was not appreciated until the intensive war-time activities made the problem acute is a case in point. During a period, January to October, a large number of marigram readings in Apra Harbour showed an average period of 47 minutes, the minimum period being 41 minutes and the maximum 53. These long period disturbances could be due to either a very long period wave in the ocean or to a relaxation oscillation of the basin associated with the unstable water level difference between the harbour and the ocean. The first possibility was ruled out as no ocean long period waves were recorded on the ocean marigrams, so it was highly probable the second possibility was the correct one. Several statements from dredging masters and harbour personnel regarding long period disturbances were investigated, but no supporting evidence was obtained from the measuring instruments.

In the model experiments, the horizontal water velocities were measured by photographing the travel of floating reflectors on the water surface. Some of these reflectors were wooden circular discs with bevelled edges, smallest diameter uppermost, to prevent float to float contact at water surface; others were of plastic buttons. In shallow water, two of these buttons were cemented together, back to back, thus forming a double-sided unit. The reflectors were of the same type as those used for road signs arranged as a system of reflecting surfaces in groups of three, in which three surfaces of each group are mutually perpendicular. Each surface is one-sixteenth inch square. These trihedral angles have the quality of reflecting light directly back to its source.

The illumination for the reflections was provided by two small high-speed flash lamps, each mounted as close to the cameras as possible. Eighty-six exposures were made on one negative in controlled time intervals during a total period of about 6 minutes. In order to prevent over-exposure of the background by the general lighting of the laboratory as a consequence of the repeated exposures, the cameras were stopped down to f/22 and the background exposure time reduced to 1/300 second. To ensure that all floats were launched simultaneously from the specified locations to give comparable photographic records, float feeding mechanisms or dispensers were installed at the fixed stations. Each dispenser was provided with a releasing gate which allowed one reflector only to be launched from a number held in the vertical tubular magazine, and this was operated by remote control. In order to be able to read the direction of the float movements, the first four exposures of each test run were taken at longer intervals than the remaining 82 exposures. The position of each reflecting float was recorded on the film at the time of each exposure, and the speeds of the floats could be calculated by measuring distances between dots and dividing by the proper time factor. A typical photographic record and computed speed of current of the named float is given in Fig. 45.

The photographic technique was varied to suit the end in view; to obtain streak photographs, the method was adopted of a cycle of camera shutter open for six seconds and closed for one second—this was to ensure good differentiation between the oscillatory motion and the current drift.

HARBOUR RESPONSE

The observed modes of harbour oscillation are shown in Fig. 44, and the fundamental and harmonic periods are summarised for the first six in the following table. Comparison with the table of Predicted Modes shows that the outer harbour east/west modes are characteristic of an open harbour; no modes such as 1A or 3A, in which reflection occurs from the west end of harbour, being in existence. Mode No. 2 from the L.S.T. landing to the open

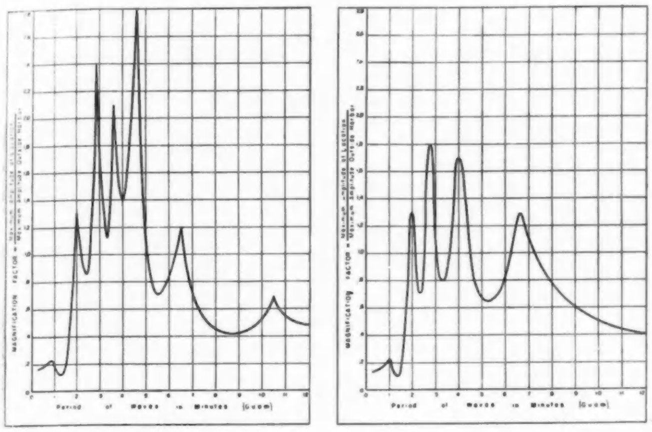
OBSERVED MODES OF HARBOUR OSCILLATION

Mode No.	Mode Description Fig.	Period in minutes at Guam. Fundamental	Harmonic First	Harmonic Second	Harmonic Third	Harmonic Fourth
1.	East-west, East end repair basin to open harbour entrance without inner breakwater.	31.5*	10.5	6.5	4.6	3.6
2.	East-west, L.S.T. landing to open harbour entrance with inner breakwater.	20.0*	6.7	4.0	2.9	
3.	East-west, south leg inner breakwater to open harbour entrance.	15.0*	5.0	3.0		
4.	North-south, Gab Gab beach to outer breakwater.	4.4*	2.2	1.5*	1.1	
5.	East-west, East end repair basin to inner breakwater.	5.7	2.9	1.9		
6.	North-south in repair basin,	3.8	1.9	1.3		

* Calculated, not observed.

Model Studies of Apra Harbour—continued

harbour entrance was not anticipated. This illustrates the major difficulty in predicting the resonant periods of a complicated basin, such as a harbour, by theoretical considerations alone; a possible mode of oscillation is not always recognised as such.



(a) Shoals JSW (b) Breakwater D-2
Fig. 46. Frequency response at LST landing in Outer Harbour.

The fundamentals of modes 1, 2 and 3, were not observed because the wave machines were not capable of producing waves of this long period without extensive modification. The fundamental and second harmonic of mode 4 were not observed because the path of oscillation was perpendicular to the exciting train, and only odd-order harmonics which result in a vertical water surface configuration about the east/west axis of the harbour were excited. The wave crests entering the harbour were curved by refraction at the entrance and by the further effect of diffraction; hence sections of the same wave crest reach and reflect from Gab-Gab beach and the outer breakwater simultaneously. Thus, the antinodes at the opposite reflecting surfaces were always of the same phase and only odd-order harmonics were excited.

The amplitude response in a few harbour locations are shown in the following tables under two different conditions, as indicated. In all cases the amplitude is expressed as a fraction of the amplitude of the wave outside the harbour.

TABLE OF HARBOUR RESPONSE OBSERVATIONS WITH SHOALS ALONE

Location	Period (minutes)	Magnification Factor	Mode No.	Harmonic
	10.5	1.7	1	1
	6.5	1.1	1	2
Repair Basin	4.6	1.1	1	3
East shore	3.6	0.8	1	4
	2.9	2.0	5	1
	1.9	1.2	5	2
	10.5	0.7	1	1
	6.5	1.2	1	2
Outer Harbour	4.6	2.8	1	3
L.S.T. landing	3.6	2.1	1	4
	2.9	2.3	2	3
	2.1	1.3	4	1
	1.0	0.2	4	3
	10.5	0.5	1	1
	6.5	0.5	1	2
Outer Harbour	4.6	0.7	1	3
Pier D	3.6	0.9	1	4
	2.9	1.1	2	3
	1.9	1-1	4	1
	1.0	0.5	4	3
	6.4	0.4	7	Fundamental
Inner Harbaur	5.0	0.4	8	do.
Dock N-1	3.8	0.6	10	do.
	2.2	0.3	11	1

This fraction is known as the magnification factor. The frequency response for the outer harbour L.S.T. landing with shoals, and with shoals and breakwater D-2, is shown in Fig. 46 (a) and (b). The horizontal water motion in the outer harbour is clearly portrayed in the diagrams of Figs. 47 and 48, in which the oscillatory components of horizontal water velocity due to

TABLE OF HARBOUR RESPONSE OBSERVATIONS WITH SHOALS AND INNER BREAKWATER D-2

Location	Period (minutes)	Magnification Factor	Mode No.	Harmonic
Repair Basin	5.7	0.8	5	Fundamental
East Shore.	2.9	0.5	5	1
	1.9	0.3	5 & 6	2 and 1
	6.7	1.3	2	1
Outer Harbour	4.0	1.7	2	2
L.S.T. landing.	2.9	1.8	2	3
	2.0	1.3	4	1
	1.0	0.2	4	3
	6.7	0.6	2	1
Outer Harbour	4.0	0.9	2	2
Pier D.	2.9	1.2	2	3
	2.0	1.0	4	1
	1.0	0.5	4	3
	6.4	0.3	7	Fundamental
Inner Harbour	5.0	0.2	8	do.
Dock N-1	3.8	0.4	10	do.
	2.2	0.3	11	1

imposed westerly surges 1 foot high of 6.5 and 1.9 minutes period are shown. Variation of the period alters the pattern considerably, a decrease of the period from 6.5 minutes increases the area, hatched horizontally, full lines, .05—.10; in fact, at periods of 4.4 and 3.8, it covers the greater part of the area from the entrance to the west end of the repair basin, Guam grid E11. Then at periods of 2.9 minutes and below, it decreases in area and favours the north side of the harbour, tending to separate into two portions, one about the entrance and the other hugging the outer breakwater from Army Port facilities to breakwater station + 30, thus

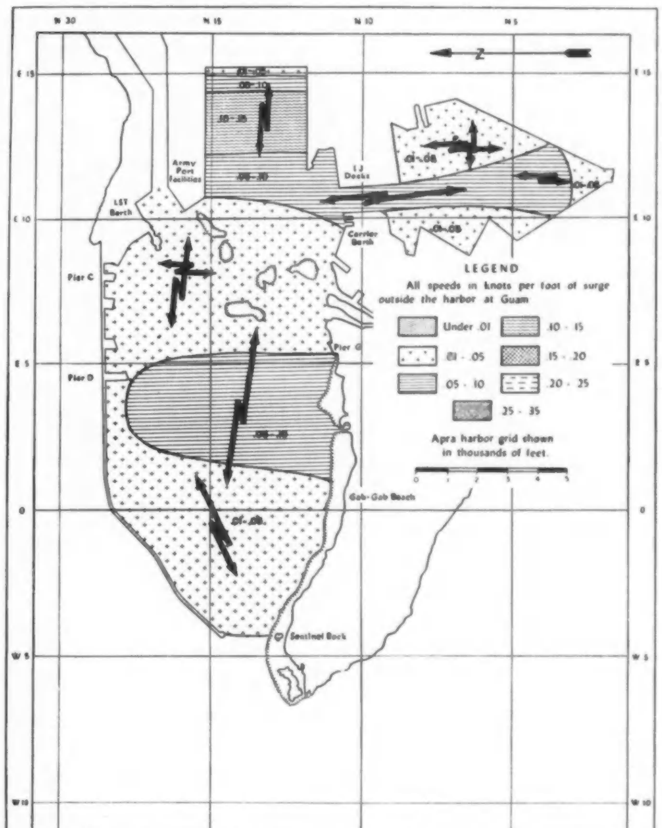


Fig. 47. Oscillatory component of horizontal water motion due to westerly surge 1-ft. high, 6.5 minutes period.

Model Studies of Apra Harbour—*continued*

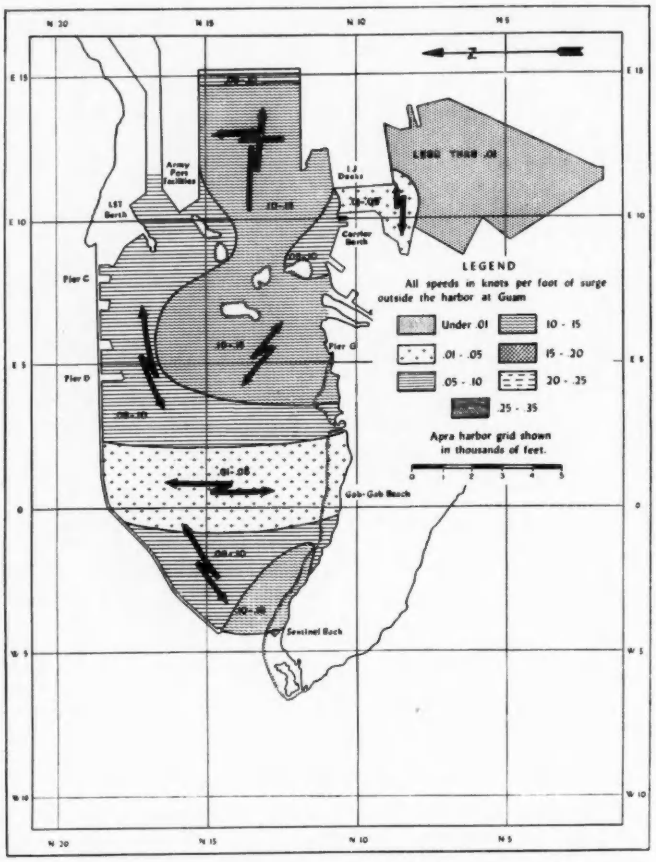


Fig. 48. Oscillatory component of horizontal water motion due to westerly surge 1-ft. high, 1.9 minutes period.

leaving at 1.9 minutes period (Fig. 48) a north/south strip from the outer breakwater to Gab-Gab beach, .01—.05, of north/south oscillation between the two boundaries.

The variation in the horizontal velocity at different locations in the harbour was due to the variation in water depth, the variation in degree of wave height amplification at the different locations, and to the presence of nodes and antinodes of the standing wave pattern, corresponding to the maxima and minima of horizontal water velocities.

RESONANT AMPLIFICATION FACTORS

The fact that the model surge amplitudes were purposely made much larger than would be obtained by scaling the expected prototype amplitudes is a source of inaccuracy, but the magnification of wave height was necessary for four reasons :

(1) To produce large enough water motions to permit visual observation of the existence of resonant conditions.
(2) To produce large enough horizontal water motions to permit accurate photographic measurements of the horizontal displacements.
(3) To produce large enough motions so that the effect of extraneous motion due to air currents and building vibration was negligible.
(4) To produce large enough horizontal water velocities to preclude the existence of laminar flow, which would result in excessive damping.

For the small values of (h/d) associated with long period waves in the prototype, the correction factor is practically unity, whereas for the wave heights used in the model study, the correction factor indicates that the velocity of the model waves was approximately 15 per cent. too high in the inner harbour, 10 per cent. too high in the repair basin, and 4 per cent. too high in the outer harbour —thus the periods are too short by the same percentage.

The requirements which must be met to ensure good modelling of wave amplication is that the damping for model and prototype are to scale, which implies that the Reynolds numbers for the flow conditions in both follow the same law of frictional resistance (either laminar or turbulent) and that the relative roughness of the bottom in both are to scale. It has already been noted (p. 10, May issue, "Dock & Harbour Authority") that the transition from laminar to turbulent flow occurs between values of R of 1,000 to 10,000:

$$R = h/\pi \ \sqrt{gd} \times 10^5$$

where h = wave height

d = water depth.

In all areas of the Apra prototype, the flow was in the turbulent range and the friction coefficient substantially constant even for a wide range of wave height; thus the resonant amplification factors were independent of wave height. In the model, if the wave heights were proportioned to scale, the Reynolds number for the inner harbour would be only R = 45, indicating laminar flow and high friction coefficients. By using magnified heights, however, the Reynolds number for the inner harbour is increased to R = 2,250. Thus, for the model studies, the Reynolds number for all harbour areas was in the transition range, with the result that the friction coefficient was close to that of the prototype and possibly slightly lower.

INNER HARBOUR RESPONSE

The effect of the inner breakwater on the response of the outer harbour was primarily due to the different modes of oscillation excited in the two cases, and comparison of the several graphs of tests, such as Fig. 46, shows that the addition of the inner breakwater eliminates the 10.5 minute first harmonic, the 4.6 minute third harmonic, and the 3.6 minute fourth harmonic, of mode No. 1, and introduces the 4 minute second harmonic of mode No. 3. The resonant peak occurring at a period of about 6.5 minutes for both cases is in the nature of a coincidence, as the 6.5 minute second harmonic of mode No. 1 is replaced by the 6.7 minute first harmonic of mode No. 2. For waves of periods less than about 3 minutes, the shoals alone were as good a reflecting medium as the shoals plus breakwater, with the result that harmonics with periods less than 3 minutes appear unchanged with or without the inner breakwater.

The response of the repair basin is greatly affected by the inner breakwater, the effect being due to both the different modes for the two cases, and the greatly reduced excitation available with the inner breakwater in place. It will be seen that the addition of the inner breakwater eliminated the disturbance due to mode No. 1 and developed that due to mode No. 5; the amplification then was only one-quarter of that for shoals alone.

The response of the inner harbour is greatly affected by the excitation entering from the repair basin, but the modes of oscillation are not affected by the addition of the inner breakwater. The outstanding difference for the two conditions was the large change in amplification factor for the 4.4 minute fundamental of mode No. 11, the response being 2½ times as great for shoals alone as for shoals plus inner breakwater. This difference was due to the fact that the fundamental period of mode No. 11 was very close to the period of the third harmonic of mode No. 1 (4.6); which in turn caused large amplitudes of water motion in the repair basin for shoals alone, and was virtually absent for shoals plus inner breakwater. Again, the 1.9 minute first harmonic of modes 9 and 10 appeared in the inner harbour when the inner breakwater was in place; hence these oscillations were excited by the second harmonic of mode No. 5 in the repair basin. At locations in the inner harbour, such as Dock N-1, where the periods of resonant oscillations were different from those in the repair basin for either condition, the response curves were very nearly the same for both conditions.

HORIZONTAL WATER MOTIONS

The distribution of the oscillatory component of the horizontal water motion for the most dangerous surge periods of 6.5 minutes, 4.4 minutes, 3.8 minutes, 2.9 minutes and 1.9 minutes, when

Model Studies of Apra Harbour—continued

shown as in Figs. 47 and 48, illustrate clearly the important dependence of horizontal water motion on depth, as explained above; they also show that much greater water motions obtain in the inner harbour than in the outer harbour, even though the vertical motion was no greater for these periods in the inner harbour than in the outer harbour.

Since any damaging effects of long period surges were due to the horizontal water movements associated with the wave motion, the figures serve to identify the most dangerous surge periods for the different harbour areas. Thus, the most severe conditions at the docking areas in the outer harbour were for the surge period of 1.9 minutes, since for this period the horizontal water velocities reached a maximum of 0.10 to 0.15 knots per foot of imposed wave height (that is, the height of wave in the ocean), and the corresponding amplitude of horizontal water motion (10 to 15 feet) was as great or greater than for any of the other predominant surge periods. For the repair basin, the 2.9 minute period condition was most severe, with velocities of 0.25 to 0.35 knots per foot of imposed wave height and displacements of 35 to 50 feet. For the inner harbour the 3.8 minute period was most severe, with velocities of 0.15 to 0.20 knots per foot of imposed wave height and displacements of 30 to 40 feet in the north-western docking areas. For all surge conditions, the L.S.T. landing was subjected to greater water motion than other docking areas in the outer harbour; the north shore of the repair basin (A.P.F.) was liable to much more motion than the east shore, and the western docking areas of the inner harbour were much more disturbed than those of the east shore.

CONCLUSIONS

The above investigations led to the following conclusions:—

(1) Apra Harbour is subject to resonant oscillation with amplification factors as high as 2 for at least five surge periods in the range from one to six minutes. Water motions characterised by velocities of the order of 0.25 knots per foot of imposed wave height may result in various docking areas as the result of such oscillations.

(2) The existing docking areas in the outer harbour (Piers C to D on the north shore, and carrier berth to Pier G on the south shore) are as favourably located with respect to surge disturbances as any possible location in the outer harbour. The L.S.T. landing area is somewhat less favourably located than the other docking areas.

(3) The repair basin is subjected to relatively great disturbances for all surge conditions. This is particularly true for the north and south shores. The east shore is the least disturbed location in the repair basin.

(4) The entire inner harbour is relatively undisturbed for surge periods of less than three minutes. For longer periods, the north-western docking areas are subjected to large disturbances, while the eastern shore remains quiet. It thus appears that the proposed location of the dry dock in the north-eastern area of the inner harbour is in a favourable position with respect to surge disturbances.

(5) The addition of an inner breakwater on the existing shoals affords some protection to the repair basin and inner harbour. The amount of protection is greatest for the repair basin, but, on the whole, the disturbances are of such magnitude that it is doubtful if the inner breakwater can be economically justified on the basis of surge protection alone.

GENERAL

Regarding these long period wave disturbances, it should be thoroughly appreciated that no modes of oscillation within the harbour will be excited unless a wave train, whose period is near one of the fundamental or harmonic periods of the harbour, enters the harbour from the open sea. Such a wave train will excite only the particular harmonics whose periods are close to that of the wave train. While it is true that in certain types of electrical oscillating systems it is possible to excite an oscillation of a longer period than that of the exciting signal, a special type of non-linearity is required, and this phenomenon of sub-harmonic resonance is never observed in mechanical systems. The harbour system is essentially a linear one, with but small non-linear contributions from the V^2 damping, and from the effect of finite wave height on velocity; hence any oscillation in the harbour requires an exciting wave train of essentially the same period. R. R. M.

(to be continued)

Regime and Rhythm in Waterways

(Concluded from page 120)

resistance applies the diameter squared measures the terminal velocity, so that this varies as the $1\frac{1}{2}$ power of the particle diameter.

Lacey, in his first paper (1929), makes an allusion to the silt transportation formula and states that the silt transporting power of a stream varies as the sixth power of the velocity as a " hitherto academic contention " and supports it by a formula:

$$Q\,f^2 = 4.0\,V^6$$

which, he says, is " general to all silt transporting channels."

This is, of course, just the inverse of Inglis' version of Lacey's formula, $V = 0.7937\,Q^{1/6}\,f^{1/3}$, given previously, and stands or falls with the Lacey rules. It should, however, be noted that it does give support to the velocity to the sixth power rule on the assumption that f is dependent on V^2/R, and $P \propto Q^{\frac{1}{2}}$.

Holmes (Principles of Physical Geology, p. 151) says that " with debris of mixed shapes and sizes the load . . . is proportional to something between the third and fourth power of the velocity. But for fragments of a given size, the largest size that can be moved is proportional to the sixth power of the velocity." This is obviously based on the terminal velocity varying as the square root of the particle diameter, so that the diameter cubed (proportional to volume) varies as the sixth power of the terminal velocity. It does not at all follow that the fraction which is " the largest size that can be moved " is constant, or follows any simple law at all.

(*Note*: According to Lacey, $f^2 \propto VS$ so that Qf^2 shows direct relation to silt carrying capacity.)

INGLIS' CANAL FORMULA

Inglis, p. 125 (B.C.R.C.), produced a formula:

$$V = 12.0\,(R^2\,S)^{2/7} \qquad (\text{" very approximately "})$$

for numerous canal sites in the Punjab, which he compares with Lacey's formula.

It is based on combined data and the formula:

$$S = 0.000474\,f_m^{1.53}/Q^{.145}$$

and $f_m = f_{VR}^{\frac{1}{2}} \,.\, f_{RS}^{\frac{1}{2}}$, which is " almost constant " (p. 129).

This may be compared with Lacey's form $V = 16\,R^{\frac{2}{3}}\,S^{\frac{1}{3}}$.

Insofar as it goes, it tends to confirm what may be termed a Lacey type of formula, substituting four-sevenths and two-sevenths for the respective powers of the hydraulic radius and slope and 12 for 16 in the coefficient. Inglis says they differ " widely " (p. 130), but the actual diagrams (p. 123) do not show very extraordinary divergence.

The ratio of $R^2\,S$ in the two formulæ and the ratio of the coefficients is not large, but a comparison with Dr. Malhotra's variation of the Lacey formula shows serious disagreement.

It should be noted that the distortion $e = y^{0.25}$ if the rule $r^{4/7}\,s^{2/7}$ is general (see Chatley on " Distortion of Scales in Models with Loose Beds," International Association for Hydraulic Structures Research, Stockholm meeting, 1948). This shows an enormous divergence from Lacey's value, which corresponds to $e = \sqrt{y}$. Inglis regards the formula $\sqrt{f^{VR}/f^{RS}}$ as a measure of the divergence of the Lacey rules from regime.

Madras Harbour Expansion.

To enable the Madras Port Trust to carry out its plans to extend the harbour southwards, the Madras Government have agreed to alienate 86 acres of the foreshore, for which the Port Trust will pay Rs. 30 lakhs, in six annual instalments.

The Port of Rotterdam

An Historic Gateway to Western Europe

By W. H. CRAWFORD.

Rotterdam is built on a sandy beach at the junction of the River Maas and the River Rotte. Owing to the fact that the mouth of the River Rhine has undergone many changes of direction over the centuries, and is not navigable to deep sea shipping, the Maas has long been the main outlet for the Rhine traffic, so that Rotterdam gradually became the main transhipment port.

It is known that two castles existed on the banks of the Rotte as early as 1283, but the exact date of the laying down of the dam is uncertain. The reasons for such action, however, are well known, as the land all round lies below sea level, and to prevent flooding at each high tide the dam was constructed at the mouth. An old dyke was built during the Roman era, and a village of fishermen and flaxgrowers existed there in the 9th century, while Vlaardingen was in existence on the banks of the Maas when Dordecht was established in 1015 A.D.

From 1300 to 1600 Rotterdam grew from a humble dyke-hamlet into a prosperous little town, and was granted civil rights in 1340.

Due to the low level of the land, the course of the Maas was continually altering and the people of Rotterdam had to fight to keep open the passage from the Rotte to the North Sea. On the 18th November, 1421, there was a terrible storm along the Dutch coast, followed by a high tide—" St. Elizabeth Flood "—which inundated the whole coastline. This action changed the flow of the Maas, the mouth of which became smaller, although numerous lesser outlets remained to the south. The silting up of the channel became so rapid that a southern passage with a depth of only 10-ft. was used. This proved unsuitable and vessels were often forced to move about the islands searching for entry. Although Rotterdam was only 18 miles from the North Sea, ships often had to cover 60 miles to reach the port, and some even discharged their cargoes into lighters. These roundabout routes were so unsatisfactory that Nicolaas Cruquius presented a plan to cut a canal through the island of Voorne, one of the southern group. This was accomplished in 1827 and brought Rotterdam within 7 hours of the North Sea. The canal was 20 miles long and 16-ft. deep, with locks at each end, but was still subject to silting.

On 21st August, 1858, Engineer P. Caland presented a plan for a new canal to cut through the spit of sand, the formidable " Hook " of Holland, and a canal was authorised for the " improvement of the waterways through Rotterdam to the sea." This was virtually the beginning of modern Rotterdam. H.R.H. The Prince of Orange turned the first sod on 31st October, 1866, and the connection was completed on 26th November, 1868. Two fishing vessels were the first to pass through in September, 1870. This canal, called the " Nieuwe Waterweg," made a straight passage from the port to the North Sea, a distance of 16 miles, but after only four years the mouth again silted up, so that there was only a depth of 8-ft. on the bar. Work was therefore recommenced, and by 1885 a depth of 17-ft. at low tide was available. From that time onwards the depth has been gradually increased, until now at low water it is 36-ft., with an average of 5½-ft. more at high tide. Thus the centuries old " wide mouth of the Maas " has been removed in its entirety and is kept firmly in check between the piers at the Hook of Holland. In this way Rotterdam, after three-quarters of a century, was equipped with an open channel without bridges or lockgates. It now takes only 1½ hours in all weathers for ships to pass from the North Sea to the quays and mooring of Rotterdam Harbour.

Wijnhaven, Bierhaven and Glashaven were a few of the earliest docks, and these were enlarged in the 17th century to accommodate deep sea vessels.

About 1870 the south side of the Maas was industrialised and a system of railway bridges constructed across the Maas. These were completed in 1878, and also connect the small island—Noordereiland—with both banks of the river. The railway bridge is a high lift-bridge with a clearance of 300-ft. at low water level, and there is also a bascule bridge for road traffic.

These bridges opened the way for industrialisation on the south bank, and as the importance of the Rhine became recognised, Rotterdam grew into a great transhipment port. This subsequently led to the development of the present dock system, which is unrivalled in Europe. The first docks in Rotterdam south, viz., Spoorweghaven, Binnenhaven and Entrepothaven, were constructed and connected with the railway system. Scarcely had another new dock, Rijnhaven, been completed, when work was commenced on the Maashaven, which was twice the size of the former. The Maashaven was completed in 1905, and two years later the corporation decided on the excavation of the Waalhaven, which is still the world's largest artificial dock basin, and south of which lies the well known airport. The Rijnhaven is used mainly by timber ships and the Waalhaven by coal and ore ships. At the town developed around these docks, a new petrol and oil dock was constructed farther westward, opposite Vlaardingen.

On the Rotterdam side of the river, S. Jobshaven and Sciehaven were built to deal with general cargo, and gradually docks grew along the north bank westwards, till in 1929 the large Merwehaven was constructed. This is a group of three docks with a common entrance.

At the commencement of the German invasion during the recent World War, there was a heavy and devastating raid in May, 1940, when the entire centre of the city was destroyed and the homes of 100,000 inhabitants demolished. Finally, in the autumn of 1944, the mass destruction of the harbour itself was carried out by the German army. This comprised the systematic blowing up of quays, transit sheds, warehouses, cranes and loading bridges. Almost two-fifths of the storage and warehouse space, nearly half the floating cranes, besides numerous shore cranes, were destroyed. Thirteen of the sixteen floating docks were sunk and the Rhine shipping fleet suffered similarly.

Following the conclusion of hostilities, a vigorous programme of reconstruction was immediately put in hand, and such satisfactory progress has been made that to-day Rotterdam is equipped with 76 floating cranes, 225 quay cranes, 20 floating dry docks, 8 shipyards, a graving dock, 28 slipways and other facilities.

Rotterdam is now engaged in completing the rehabilitation of the town and port, and is rapidly regaining the high prestige of pre-war years. When Queen Wilhelmina returned to Holland, at the end of the war, she gave the city a new motto as an expression of the port's resurrection, " Sterker door Strijd," which means " Stronger through Struggle." This characterizes the efforts of the people of Rotterdam in the great task before them.

Subsidence of Long Beach Naval Shipyard

Methods Adopted to Avert Collapse

By GEORGE W. GRUPP

The large naval shipyard on Terminal Island, Long Beach, California, consisting of seven piers, three drydocks and many fully-equipped buildings, was completed in 1943 at a cost of $65,000,000. Apparently, shortly after it was finished, it began to sink at an average rate of about one foot per year. Even though preconstruction soil and subsoil tests indicated that there was adequate support for the weight of the shipyard, yet in 1945, two years after it was built, the ground in some places of the yard has sunk 4½ feet below its original level.

Studies were undertaken at once to determine the causes, and most of the engineers engaged in the investigations agreed that the sinking was due to the down-draw pressures caused by the removal of gas and oil in the nearby Wilmington oil field.

There the matter rested until renewed interest was stimulated in 1948, when the ground about 1,500 feet from the naval shipyard sank and damaged the underground structure of the large Southern California Edison Company power plant.

Subsidence of Long Beach Naval Shipyard—continued

Further investigations revealed that something must be done to avert more serious damage. For example, subsidence along the waterfront ranged from 3-ft. to 5½-ft. The surrounding ground of Drydock No. 1 had sunk 6 feet, and the drydock's head end was 2½ feet lower than its seaward end. All buildings in the shipyard were beginning to lean in a north-easterly direction. Then, to further complicate matters, the earth's horizontal slippage, due to a minor earthquake in November 1949, resulted in a rise of the ground in some sections and a sinking in other areas at an accelerated rate.

All of this was too serious to be overlooked. Private engineers and petroleum geologists, and the technical experts of the U.S. Geological Survey, U.S. Coast and Geodetic Survey, U.S. Bureau of Mines, and Stanford University Research Institute were engaged by the Bureau of Yards and Docks of the U.S. Navy to study and solve the problem. At the same time, the Bureau also obtained the co-operation of the Long Beach Harbour Board, and local oil men, engineers and geologists.

After the United States Coast and Geodetic Survey had made a precise level and transit survey, four methods were employed to save the shipyard. First, dykes and concrete walls were built around certain portions of the shipyard, to prevent its being damaged or destroyed by flooding, since the total subsidence by 1965 is expected to range from 18 to 23 feet, as compared with the present maximum of 11 feet at the centre of the subsidence area. Second, the rate of oil removal is being reduced. Third, treated salt water is being pumped into the oil zones to restore the subsoil reservoir pressure to reduce or stop subsidence. And fourth, many structural changes have been made.

Some of these changes consist of building an earth dyke to protect the north and north-east boundaries of the yard, and of raising the level of the Long Beach Harbour Board's Wharf " E " with an earth fill to protect the east boundary. The west boundary is protected by the U.S. Naval station which has only suffered minor subsidence.

Naturally, the waterfront facilities along the south boundary are the most valuable for they are needed in transferring machinery, materials and men between ships and piers. Also, since cranes of 25 to 50 ton capacity operate the full length of both sides of each pier and around all drydocks, a concrete wall has been built around the piers and along the quay between the piers and the drydock entrances. The pier wall is " T " shaped to provide a platform for the handling of ship's lines. All bollards and cleats as well as steam, electric, fresh water, salt water and telephone lines have been raised to the level of the platform, and a timber fender system has been included to protect the wall from damage by ships.

Pump pits have been built to remove storm water from the shipyard, and sixteen hydrostatic wells have been uniformly placed around Drydock No. 1 to prevent uplift. The caisson seats of Drydock No. 1 were raised 6 feet and those of Drydocks Nos. 2 and 3 were raised 4½ feet. This was accomplished by bolting precast concrete blocks to the caisson seats.

These are only a few of the changes made to save the shipyard from destruction by subsidence. The effectiveness of these charges will not be known for at least five years. Keen interest is centred on the results of pumping treated salt water into the subsoil which it is hoped will restore pressures which will keep the ground from sinking any further.

International Congress of Refrigeration

The International Congress of Refrigeration, founded in 1908 by special Convention Treaty between the Governments of the principal powers, is universally recognized as a movement established for the promotion of the methods, applications and materials of the refrigeration industry.

The Eighth Congress, which takes place in London from August 29th to September 11th, 1951, is the world-focus of refrigeration, supplying to those interested in all phases of this applied science, up-to-date and authoritative information on the subject. H.M. Government is providing accommodation for the meetings at Church House, Westminster, and Official Receptions will be accorded to delegates in London and other parts of the country.

Scope of the Congress Papers and Discussions

Under the organisation of the International Institute of Refrigeration, study of the scientific, technical, engineering, and economic aspects of refrigeration is conducted by seven International Commissions as follows :—

Commission I. Scientific problems of low temperature physics and thermodynamics; industries of the very low temperature and of the rare gases.

Commission II. Physical-technical problems of industrial refrigeration.

Commission III. Application of refrigeration to perishable foods with regard to their physical, chemical and biological characteristics and to their temperature.

Commission IV. Refrigerating machinery and apparatus; refrigerating plants and their operation; test methods.

Commission V. Application of refrigeration to entrepôts for preserving perishable foods, ice factories and chemical industries.

Commission VI. A. Transport by water. B. Transport by land.

Commission VII. Research, education, general economics, statistics, legislation, propaganda..

Of the many papers given in these seven Sections, the following will be of special interest to readers of this Journal :—

Thursday, August 30th.

" Comparison between direct and indirect cooling for Freon 12 cargo refrigeration plants." I. Brandin (Sweden).

" Avoiding Moisture Trouble on Marine Refrigerating Plant." P. B. H. Brown (Great Britain).

" Defrosting Processes with Dry Surface Air Coolers." J. D. Farmer (Great Britain).

" Heat Transmission through Ship's Insulation." A. J. M. Smith (deceased) with comments by F. H. Schofield, to be presented by K. C. Hales (Great Britain).

Monday, September 3rd.

" The Sea Transport of Pears and Apples from Australia and New Zealand." W. M. Carne and J. C. Walsh (Australia).

" Transport of Bananas from West Africa to the Mediterranean." Fr. Dombre (France).

" Some Biological Aspects of the Overseas Storage of Tropical Fruits." Dr. E. R. Leonard (Great Britain).

" The Overseas Transport of Chilled and Frozen Beef." (Dr. J. R. Vickery, N. E. Holmes and K. C. Hales (Australia and Great Britain).

Tuesday, September 4th.

" Use of insulated and refrigerated Containers for the Transport of Perishable Foodstuffs by Rail, by Land and by Water." T. A. Eames (Great Britain).

" The Calculation of Refrigerator Car Performance." E. W. Hicks and J. R. Vickery (Australia).

" Two Practical methods of measuring the coefficient of heat transmission of Refrigerated Railway Cars." Dr. D. Palmieri (Italy).

" Conditions to be recommended for the construction and use of Containers and Refrigerated Trucks for the purpose of drafting a Code." M. Balensi and P. M. Detanger (France).

Further particulars and application forms for membership may be obtained from The Secretary, Eighth International Congress of Refrigeration, Dalmeny House, Monument Street, London, E.C.3.

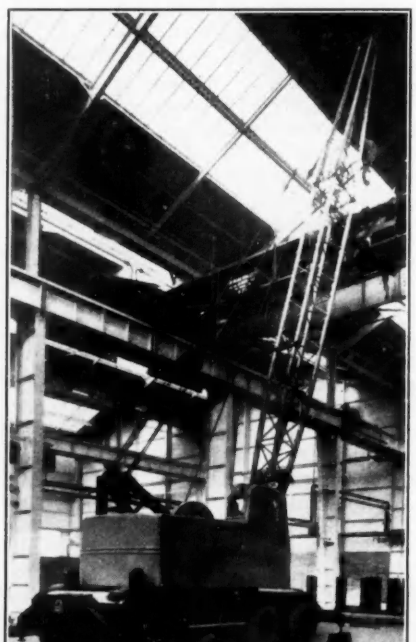
Manufacturers Announcements

Large New Mobile Crane

Messrs. Steels Engineering Products Ltd., recently announced that the new Coles MILO 20-ton mobile crane, which is claimed to be the second largest of its kind in the world, is now in production, and the manufacturers have already received many orders from both home and overseas. The first model to be delivered in the Home Market, has been supplied to Messrs. C. A. Parsons, Tyneside Engineers, and is being used to erect new steel frame workshops and overhead cranes. The time saved by its use for this work is estimated to be 85% and the saving in the number of men employed has led to a reduction in building costs.

The new crane has a strut jib which can be varied in length to suit the work upon which it is engaged. When equipped with 30-ft. centres jib it will lift 20 tons at 10-ft. radius, but alternative lengths are available up to 80-ft. centres, when loads can be lifted to a height of 83-ft. above the ground and out to as great a radius as 74-ft.

This model may be alternatively diesel/electric or petrol/electric and it operates on the Coles variable voltages system, which has the following advantages: simplicity of control, accuracy of movement, smooth acceleration, creeping speeds, lowering under



power and an automatic speed/weight compensation.

Loads up to 10 tons may be lifted and carried by the crane with outriggers housed, but it is considered better to handle heavier loads with the telescopic outriggers extended, and this adjustment by the slinger takes only a few seconds The superstructure slews 360° in either direction without limitation, and the driver, seated in a forward position on the slewing superstructure, has a perfect view of the load and hook in all positions

Interesting safety devices include the safe load indicator, which gives visible and audible warning of any tendency to overload at any position of the jib, safety limit switches on the hoist and derrick motions, patented reversible steering which permits natural movement of the hand wheel regardless of the position of the superstructure on the chassis, and the slewing safety clutch. The brakes are electro-magnetic and applied automatically to the hoist and derrick motions, so that the crane operator is not confused by a multitude of levers. The travel speed is up to 8 miles per hour and the crane moves easily on 10 pneumatic tyres, whilst the hoist speed varies in accordance with the weight that is being lifted. Another important feature is the short tail radius which permits complete rotation of the superstructure in restricted spaces, which together with the low overall weight, makes the crane exceedingly mobile in spite of its great size and power.

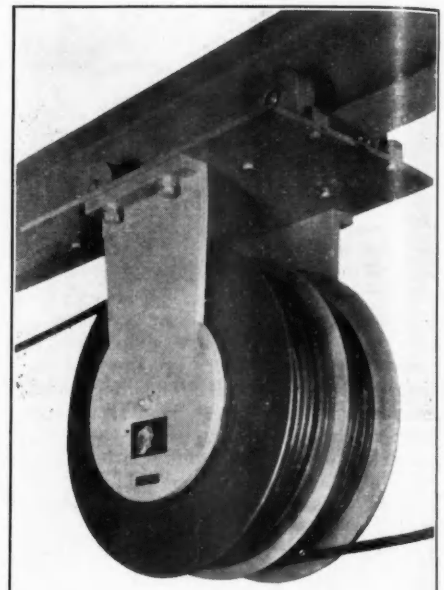
Modern Contactless Electric Cable Reels for Dock and Harbour Work

A specialised application of the "Wayne" self-winding electric cable reel that is particularly suitable for dock and harbour use, and for out-of-doors operation generally, has recently been developed. This is the patent Super 24/4/4 Trailer reel, being an important addition to the range manufactured by Power House Components Ltd., King Street, Nottingham, under the direction of David Rushworth and carrying the registered trade mark "P.H.C."

The trailer reel is essentially a double type which pays out two lines of cable in opposite directions, so that the reel can be placed in the centre of the work and double the amount of cable handled because the payout is in two directions at once, whilst current carrying slip-rings are eliminated. The trailer reel positions itself at points midway between the static electrical connection and the equipment being served, such as, for example, a dockside crane or electric hoist, but it must move along the rolled steel joist which carries the hoist, or otherwise the cable attached to the supply point would sag as it is paid off the drum. An important feature is that the rubber cable is not broken between the point of contact with the machine being supplied with current and at the other end of the cable where it is connected to the electric supply point. Contactless reels of this type are very suitable for operation in marine atmospheres generally, as well as in explosive, inflammable, moisture, or dust-laden atmospheres.

These reels also have numerous applications in shipyard and marine engineering workshops generally, including the operation of machine tools and other electrically-driven equipment involving position movement. The almost universal practice of using long lengths of trailing cable has many disadvantages, including deterioration by contact with water, oil and other products, and also serious risk of electric shocks and short circuits.

The "Major" and "Super" reels, for example, are specially designed for machine tools, portable tools and similar equipment,



taking respectively cables of 0.300—0.625-in. diameter up to 60-ft. long, and 0.625 — 1.250-in. diameter up to 150-ft. long for large machine tools. Either of the two models also can be of the "dual" type for long travel lathes and other tools, that is with two independently operated drums side by side, so that one can pay out whilst the other can wind up.

In addition to these cranes, hoist, machine tool and general engineering applications, "Wayne" reels have numerous uses on board ship, such as for vacuum cleaners, allowing easy adjustment to suit the individual operator and eliminating long lengths of unsightly or dangerous flex.

British Standard for Wire Suspension Ropes for Lifts and Hoists

This revised British Standard (B.S. 329/1951), was undertaken at the request of the Lifts, Hoists and Escalators Committee for the inclusion of eight strand ropes, and ropes having a tensile range of 70 to 80 per sq. in., the tensile ranges now included being 70 to 80 and 80 to 90 tons per sq. in. A departure from previous practice is that this revision now expresses the size of rope by the diameter and not by the circumference, a change which is considered to be in the best interests of all concerned, and which now brings British practice into conformity with the current practice in other countries. The Foreword gives guidance on the use of these ropes and recommendations for the diameters of drums, sheaves or pulleys. Copies can be obtained from the British Standards Institution, 24, Victoria Street, London, S.W.1, price 3s. post free.